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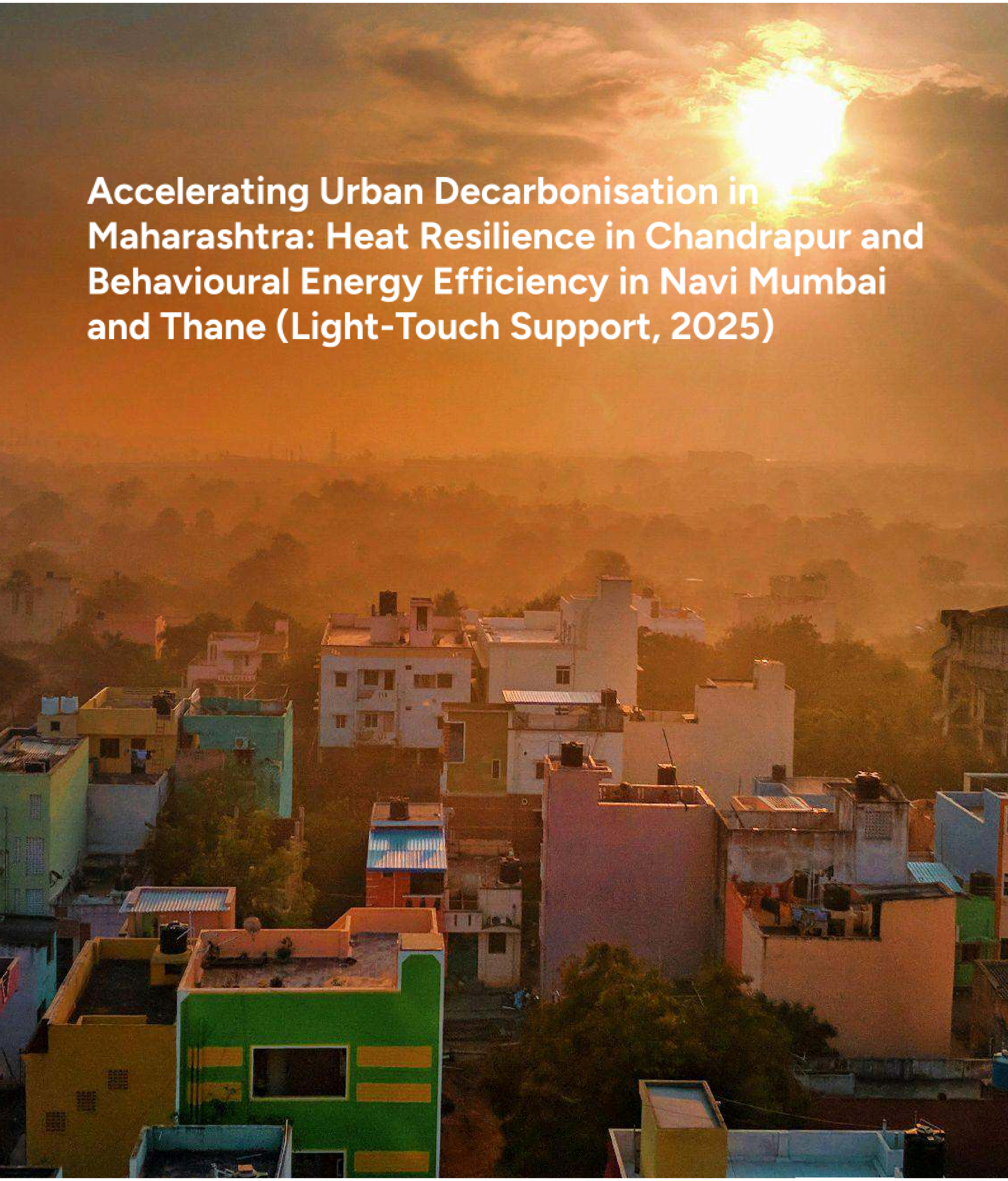


Accelerating Urban Decarbonisation in Maharashtra: Heat Resilience in Chandrapur and Behavioural Energy Efficiency in Navi Mumbai and Thane (Light-Touch Support, 2025)

Technical Partners:

Aga Khan Agency for Habitat India

SVARA SCAPE

Disclaimer

Message

Smt. Pankaja Gopinath Munde
Honourable Minister for Environment and Climate Change,
Animal Husbandry, Government of Maharashtra

Maharashtra has set a clear and ambitious vision for its future—one that balances economic growth, social equity, and environmental sustainability. Under the state's long-term development agenda, including Vikasit Maharashtra 2047 and the State Action Plan on Climate Change, the Government of Maharashtra is committed to building climate-resilient cities, strengthening energy security, improving quality of life for citizens, and positioning the state as a national and global leader in low-carbon development.

Cities lie at the heart of this vision. As engines of growth and innovation, Maharashtra's urban centres also account for a significant share of energy demand and greenhouse gas emissions, particularly from the buildings and energy sectors. Addressing these challenges is not only essential for meeting climate goals, but also for reducing energy costs, improving thermal comfort, enhancing public health, and ensuring inclusive urban development—especially for communities vulnerable to heat.

The report presented here represents a meaningful step in translating the state's climate and development vision into city-level action. Developed through close collaboration between the Environment and Climate Change Department, the State Climate Action Cell, urban local bodies, and C40 Cities, this work focuses on moving decisively from planning to implementation. By advancing High Impact Actions on decarbonisation through net-zero municipal buildings, rooftop solar deployment, cool and green roofs, behavioural energy efficiency and green municipal procurement, the programme supports Maharashtra's priorities on clean energy transition, climate adaptation, and sustainable urban infrastructure.

The successful notification and implementation of Cool Roof Bye-laws in Amravati stands as a strong example of how evidence-based planning, sustained technical support, and effective state–city coordination can translate climate priorities into enforceable urban policy aligned with Maharashtra's goals on heat resilience and low-carbon growth. This leadership is further reinforced by parallel successes in other cities, including the development of Net Zero Municipal Buildings Action Plans in Mumbai and Panvel, behavioural energy efficiency and rooftop solar programmes in Navi Mumbai and Thane, and household-level cooling pilots in Chandrapur demonstrating measurable reductions in indoor temperatures and energy demand. Together, these implementation-ready roadmaps highlight Maharashtra's ability to move from pilots to policy, and position the state as a national leader in delivering scalable, replicable urban climate solutions for cities across India and the Global South.

I commend the Environment and Climate Change Department, the State Climate Action Cell, the Urban Development Department, the Energy Department participating municipal corporations, and our technical partners for their commitment and collaborative spirit. These reports are not an end in themselves, but practical tools to support cities as they deliver on Maharashtra's broader vision of resilient, energy-efficient, and people-centred urban development. I am confident that the learnings from this initiative will inform future policies and inspire cities across India and the Global South.

Message

Smt. Jayashree Bhoj
Secretary, Department of Environment and Climate Change
Government of Maharashtra

The Government of Maharashtra's climate and development agenda recognises that effective implementation of climate actions at the city level is critical to achieving the state's long-term goals on sustainability, resilience, and economic competitiveness. As articulated through Vikasit Maharashtra 2047, the State Action Plan on Climate Change, and sectoral policies on energy and urban development, the state is committed to enabling cities to adopt low-carbon pathways while strengthening institutions, improving service delivery, and safeguarding vulnerable communities.

This set of project reports reflects a deliberate effort to operationalise that vision. Built upon the Maharashtra City Decarbonisation Roadmap, in partnership with C40 Cities, the work moves beyond aspirational targets to provide cities with implementable High Impact Actions, institutional arrangements, and monitoring frameworks in the energy and buildings sector. The emphasis throughout has been on alignment—between city priorities and state policy levers, between climate objectives and development outcomes, and between technical ambition and administrative feasibility.

Four cities—Mumbai, Panvel, Nashik, and Amravati—now have implementation-ready roadmaps of selected high impact actions that support state priorities such as scaling renewable energy, improving energy efficiency in public assets, enhancing thermal comfort, and strengthening procurement systems. Three additional cities—Thane, Navi Mumbai, and Chandrapur—have been supported on immediate actions that build readiness while drawing on the tools and learnings from the deep-dive cities. This tiered model reflects a scalable pathway for extending climate action across Maharashtra's diverse urban landscape.

Equally significant is the strengthening of institutional capacity at both city and state levels. Through sustained consultations, knowledge-sharing sessions, and thematic discussions, officials have been better equipped to integrate climate considerations into budgeting, planning, procurement, and regulatory processes. The development of state-level knowledge products on rooftop solar and green municipal procurement, as well as formal policy inputs to the Urban Development Department, further embeds these learnings within government systems.

Anchored by the State Climate Action Cell, this initiative has also fostered a collaborative ecosystem—bringing together cities, state agencies, utilities, financial institutions, and knowledge partners—to support coordinated action and continuous learning. This foundation will be critical as Maharashtra advances its clean energy transition, explores innovative financing mechanisms, and engages with national and international climate initiatives, including Just Energy Transition frameworks.

These reports are intended as living documents that support ongoing implementation and policy refinement. They reflect Maharashtra's commitment to evidence-based decision-making and climate action that delivers tangible benefits for citizens while advancing the state's long-term development vision.

Message

Shri Abhijit Ghorpade
Director, State Climate Action Cell (SCAC)
Department of Environment and Climate Change
Government of Maharashtra

Maharashtra, India's one of the most industrialised and urbanised states, has drafted its Viksit Maharashtra 2047 vision to achieve a USD 5-trillion economy through a sustainable and inclusive approach, while managing rapid infrastructure and construction expansion. Reflecting its leadership and commitment, Maharashtra has mobilised climate action across cities, with 43 AMRUT cities formally committing to the global Race to Zero initiative. The buildings sector accounts for nearly 37 percent of India's annual primary energy consumption, a share that is projected to increase substantially in the absence of timely and effective interventions.

Cities assume a critical role in shaping the trajectory of climate action, particularly as building stock is expected to grow significantly by 2030. In response, the Department of Environment and Climate Change, in collaboration with C40 Cities and with technical support from Environmental Design Solutions (EDS), developed the Maharashtra City Decarbonization Roadmap for the Energy and Building Sector in 2023, covering 43 AMRUT cities across the State, supporting cities in achieving net-zero emissions by 2050. As part of the roadmap's implementation, seven cities were supported on high-impact actions aligned with local priorities, while remaining consistent with state and national objectives.

This resulted in the development of: 'Net-zero energy action plans for public buildings in Mumbai and Panvel cities', 'Roadmap for accelerating rooftop solar deployment in Nashik city', 'Cool / Green roof policy roadmap for Amravati city', 'Identification of cooling pathways for low-income settlements in Chandrapur city', 'Development of behavioural energy efficiency and renewable energy adoption programmes for municipal buildings in Navi Mumbai and Thane cities.'

In addition, policy notes and guidance documents addressing cross-cutting challenges were also developed. This included 'Road to Renewable Cities', a knowledge product supporting cities in their clean energy transition and 'Greening Municipal Procurement', a step-by-step guide for urban local bodies, that centres "procurement" in the climate action dialogue.

This body of work has been undertaken through close coordination with urban local bodies, relevant state departments and agencies, technical experts, and partner organisations. It reflects an evolving approach towards action-oriented and implementation-focused climate planning, grounded in local realities, informed by analytical evidence, and designed to support scalability and replication across the State.

The Maharashtra State Climate Action Cell remains committed to supporting cities in mainstreaming climate considerations within the urban built environment and strengthening institutional capacities for sustained climate action. The roadmaps, action plans, policy recommendations and knowledge products presented herein are expected to facilitate accelerated implementation, promote innovation, and contribute meaningfully to Maharashtra's transition towards a low-carbon and climate-resilient future.

Foreword

Naim Keruwala
Regional Director, South and West Asia
C40 Cities

Maharashtra's cities are at the forefront of India's urban climate transition. Through the Maharashtra City Decarbonisation Roadmap for the Energy and Buildings Sector, 43 cities across the state have committed to ambitious, city-led pathways that align with India's long-term climate goals and demonstrate how subnational leadership can drive climate action at scale. This collective approach positions Maharashtra as a model for other states accelerating India's clean energy transition.

Rapid urbanisation, rising energy demand, and increasing exposure to extreme heat and climate risks underscore the urgency of accelerating urban climate action that delivers tangible benefits for residents while supporting long-term economic growth. C40's support to seven cities (Mumbai, Panvel, Nashik, Amravati, Thane, Navi Mumbai and Chandrapur) through development of high impact action roadmaps and critical actions on energy transition and knowledge products are aimed at advancing implementation, and providing cities with the necessary tools and frameworks. .

This suite of reports marks an important milestone in Maharashtra's urban decarbonisation journey. Developed in collaboration with the Government of Maharashtra, seven municipal corporations, and technical experts; these roadmaps demonstrate how cities can use their regulatory, operational, and purchasing power to drive systemic change at scale. Together, they outline practical and implementable pathways to reduce emissions, improve energy efficiency, and strengthen resilience across the energy and buildings sector; one of the most critical and cost-effective areas for urban climate action. The reports focus on key levers available to cities today, including cool and green roofs, rooftop solar, net-zero municipal buildings, behavioral change, and sustainable procurement, translating ambition into clear, actionable steps.

I commend the Environment and Climate Change Department of Government of Maharashtra, Climate Action Cell on its efforts in achieving this significant milestone and collaboration. C40 also acknowledges the engagements and support extended by the Departments of Urban Development, Energy Department along with the Maharashtra Institution for Transformation (MITRA) and seven cities in developing these roadmaps.

C40 looks forward to further supporting Maharashtra's cities to implement and mainstream climate actions supporting objectives of Vikasit Maharashtra 2047 and State Action Plan on Climate Change.

Acknowledgements

This report has been developed as part of the Maharashtra City Decarbonisation Roadmap, with the aim of supporting cities in advancing high-impact action in the energy and buildings sector. The preparation of this compilation would not have been possible without the collective efforts, insights, and collaboration of multiple institutions and individuals across city, state, and national levels.

We would like to express our sincere appreciation to the Environment and Climate Change Department, through the State Climate Action Cell (SCAC), the Urban Development Department, the Energy Department of Government of Maharashtra, and the Maharashtra Institution for Transformation (MITRA) for their leadership, guidance, and continued support throughout the programme. Their commitment has been instrumental in enabling cities to translate climate ambition into actionable and implementable pathways.

We are deeply grateful to the municipal leadership and officials of Chandrapur, Navi Mumbai, and Thane, whose active participation, data sharing, and strategic inputs shaped the High-Impact Action Roadmaps and implementation frameworks reflected in this report. Their openness to innovation and sustained engagement have been central to the outcomes achieved under this phase of work.

We also extend our sincere appreciation to the technical partners and subject-matter experts such as Aga Khan Agency for Habitat, and SvaraScape for their valuable contributions to analysis, stakeholder engagement, and the development of the roadmaps across the seven cities.

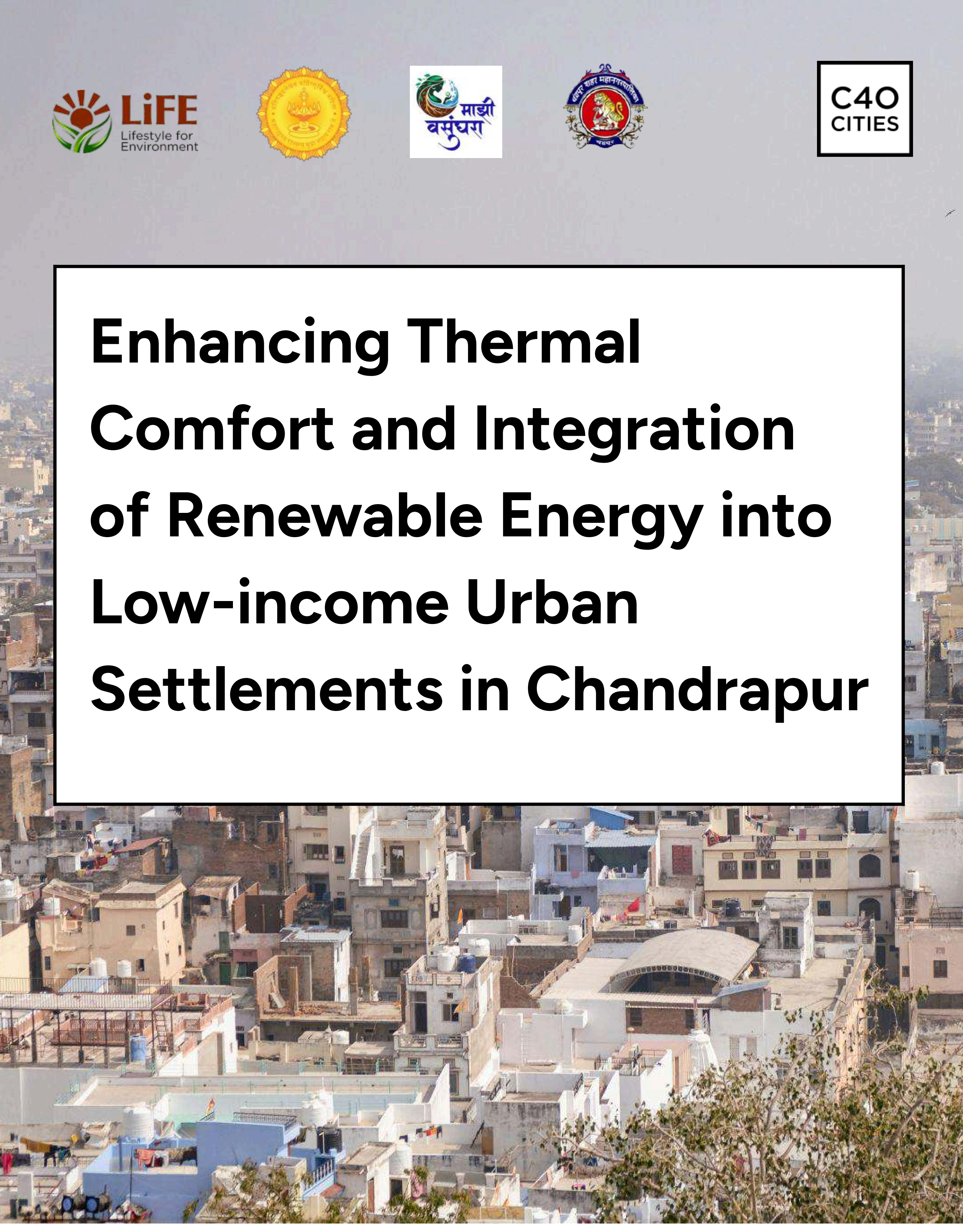
Finally, we thank all stakeholders; public institutions, practitioners, and partners for contributing their time and perspectives. This report reflects a shared commitment to advancing clean energy, low-carbon buildings, and climate-resilient urban development across Maharashtra.

Preface

C40's prior engagement on structuring Mumbai's Paris Agreement aligned Climate Action Plan (MCAP) highlighted the Energy and Buildings sector as one of the major contributors of GHG emissions in the city. Taking cues from MCAP and building on the commitment by 43 cities in Maharashtra to prepare and implement city-level decarbonization roadmap; C40 supported development of a roadmap for transition of the energy and building sector. Launched by the Environment and Climate Change Department of Maharashtra in December. 2023 this Decarbonization Roadmap is a city-level template that outlines a pathway to decarbonisation supporting the energy transition, upscaling energy efficiency, reducing GHG emissions, and reliance on fossil fuels, and lowering energy operation costs.

Building on the Maharashtra City Decarbonisation Roadmap, C40 supported seven (Mumbai, Amravati, Panvel, Nashik, Chandrapur, Navi Mumbai, Thane) out of the 43 cities included in the first phase of this work which was focused on developing implementation frameworks for clean energy and low-carbon buildings during 2024-25. These roadmaps focus on identifying priority actions with the greatest mitigation and co-benefits potential, grounded in local data, institutional realities, and market conditions, while embedding considerations related to governance, financing, and delivery.

This compilation brings together key reports from C40 Cities' light touch initiatives in Maharashtra cities. The initiative across Chandrapur, Navi Mumbai, and Thane demonstrated a range of practical, low-cost interventions to improve thermal comfort, energy efficiency, and renewable energy adoption in diverse urban contexts. In Chandrapur, targeted pilot demonstrations in 10 low-income households combined high Solar Reflectance Index (SRI) cool roof paints, lime-based coatings, insulating roof layers, passive cooling measures, and solar-lite solutions, achieving 3–6°C reductions in indoor temperatures, 20–25% lower cooling energy demand, and greater resilience during power outages. In Navi Mumbai and Thane, audits, staff engagement, and low-cost operational changes across 10 municipal buildings per city—including offices, stadiums, and auditoriums—revealed 25–35% total energy savings potential, with 5–10% achievable through behavioural change alone, while also highlighting opportunities for rooftop solar scaling. Across all three cities, light-touch support enabled actionable pilots, quantified benefits, and institutional learning, providing replicable models for heat and energy interventions within existing municipal capacity.



Enhancing Thermal Comfort and Integration of Renewable Energy into Low-income Urban Settlements in Chandrapur

Technical Partner:

Aga Khan Agency for Habitat
India

Executive Summary

As India prepares for 270 million new urban residents by 2040, its cities face rising heat stress, growing energy demand, and increasing pressure to provide thermally comfortable, low-carbon housing. Buildings already account for a major share of national electricity use and emissions making affordable cooling solutions an urgent priority. Chandrapur, in eastern Maharashtra, represents a critical test bed. One of India's hottest cities, with summer temperatures reaching 48°C, Chandrapur's 320,379 residents, many living in dense, low-income settlements, experience extreme and prolonged heat risk.

The project combines community engagement, technical analysis, and government collaboration. A Listening Workshop with 30 residents revealed severe heat-related health impacts, high electricity bills, and limited access to cooling. A Housing Mela with 110+ participants demonstrated simple retrofits cool roof coatings, lime plaster, ventilation improvements that can reduce indoor temperatures by 3–5°C, prompting immediate community interest. Parallel consultations with the municipal corporation secured a commitment to develop a heat-resilient housing retrofit plan.

Technical assessments of 10 representative low-income homes evaluated roof and wall retrofits using both real-world measurements and Design Builder simulations. Roofs being the most heat-exposed showed the greatest reduction potential. Cool tiles, high-SRI reflective coatings, and mosaic finishes lowered indoor temperatures by 2–5°C and improved comfort hours by 30–50%. Reflective paint on metal roofs reduced peak heat by up to 4°C. Wall treatments such as lime plaster added 3–3.5°C of cooling while improving moisture performance. Combined roof-and-wall packages delivered the highest benefits 3–6°C reductions and up to 50% more comfort hours.

To reduce electricity demand, the project also evaluated renewable micro-solutions such as solar exhaust fans, BLDC fans, solar-powered coolers, and DC home kits. These systems support cooling while addressing frequent power outages in informal settlements.

Citywide scaling presents significant potential: low-income settlements in Chandrapur contain 690,000 m² of roof area, often recording indoor temperatures 6–8°C higher than outdoors. Treating even 50% of this area (350,000 m²) with cool roof interventions by 2030 could reduce household temperatures by ~4°C, cut residential cooling demand by 20–25%, and save 8–10 GWh of electricity annually during peak summer load. Standardized solution packages, quality assurance protocols, and facilitation desks make adoption practical and affordable (e.g., ₹15,000–20,000 for solar-lite kits; ₹50,000–60,000 for cool roof packages).

This assessment demonstrates that affordable, scalable, and community-driven solutions can deliver meaningful thermal comfort in high-heat cities without requiring expensive technologies. By blending traditional materials, modern performance testing, and renewable micro-systems, the project establishes a practical pathway for heat resilience in low-income urban housing, one that can be replicated across India and other heat-stressed regions.

1. Introduction: Chandrapur City and Urban Heat Stress

A. City Context

Chandrapur, a municipal corporation in eastern Maharashtra, covers 54.05 km² with a population of 320,379 and an average density of 5,928 persons/km². Known as the "City of Black Gold," the Chandrapur economy centers on coal mining, cement production, and the Chandrapur Super Thermal Power Station. Ward-level densities vary dramatically, from 26,078 persons/km² in Ekori Mandir to sparse peripheral areas, with older core wards like Jatpura and Bhana Peth exhibiting compact, high-density built forms. Urban expansion between 2010 and 2025 has driven outward growth, increased built surfaces, and mining encroachment, particularly toward the south and west.

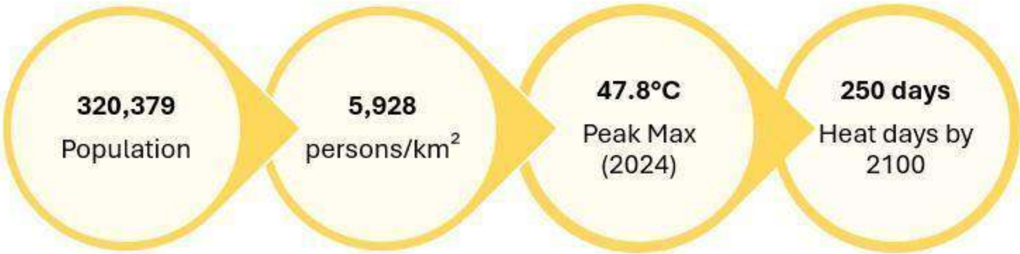


Figure 1 : Demographics and Climate Stress Indicators

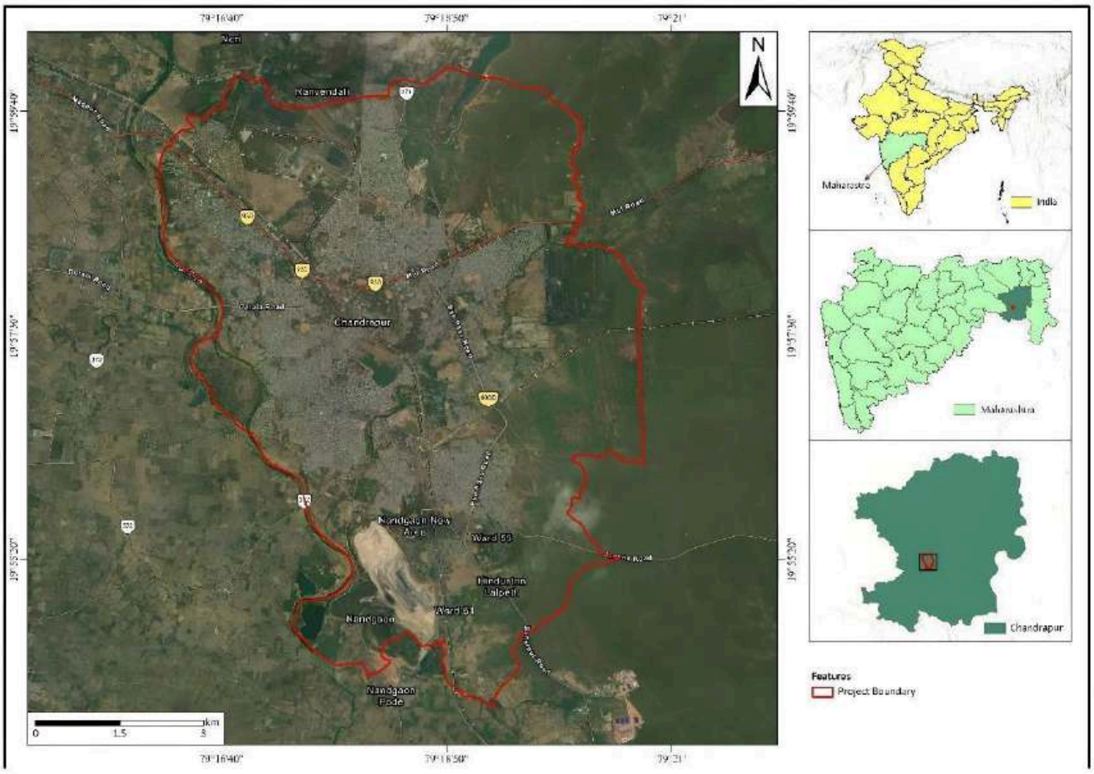


Figure 2 : Chandrapur Administrative Boundaries

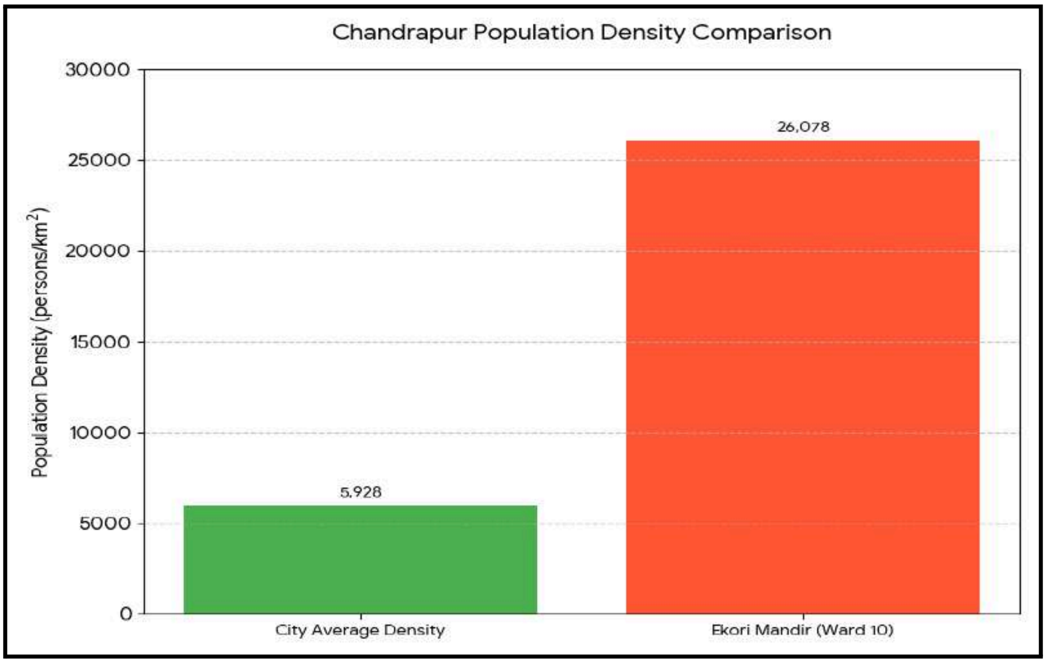


Figure 3 :Chandrapur Population density Comparison

1) Heat Vulnerability

Chandrapur ranks among Maharashtra's most heat-stressed cities. Long-term warming trends show rising daytime maximums and warming nights, reduced diurnal range and intensifying afternoon heat stress. Land Surface Temperatures in peak summer (April–May) range from 32°C in vegetated fringes to 48°C in mining zones, with ward-level averages reaching 42.22°C in M.E.L. Prabhag and 41–42°C in dense wards like Babu Peth and Vitthal Mandir.

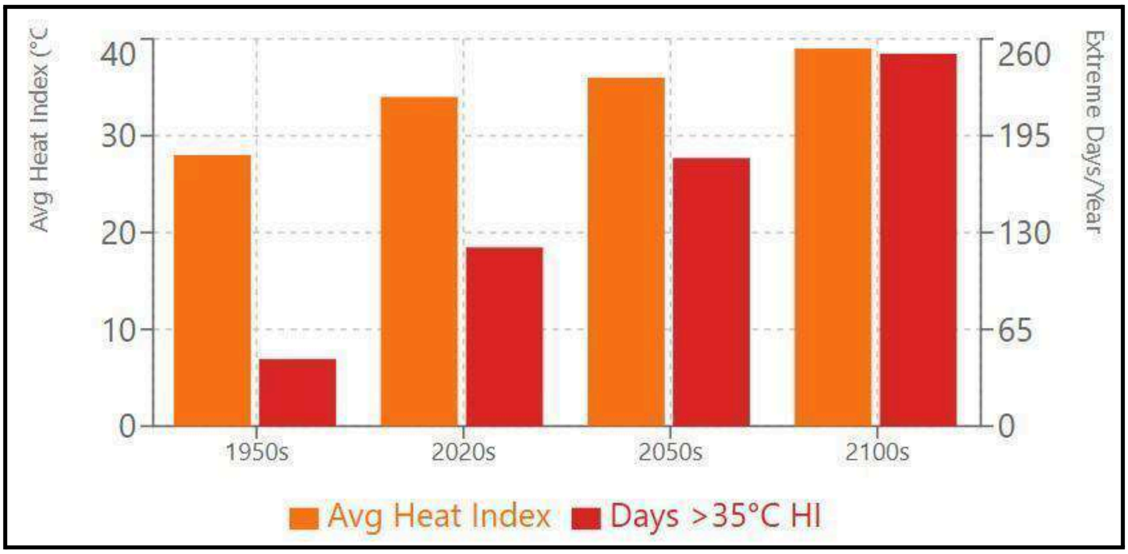


Figure 4 : Heat index Projection & Extreme Heat Days (1951-2024)

Heat Index projections indicate severe escalation: annual average HI is expected to exceed 39°C by 2100, nearly 9–11°C higher than mid-century levels. Extreme heat days (HI > 35°C) will surge from under 50 annually in the 1950s to nearly 250 by century's end approaching year-round exposure. The state Heat

Wave Action Plan designates Chandrapur as high-risk due to frequent severe heatwaves amplified by Urban Heat Island effects from mining, thermal infrastructure, bare land, and sparse vegetation.

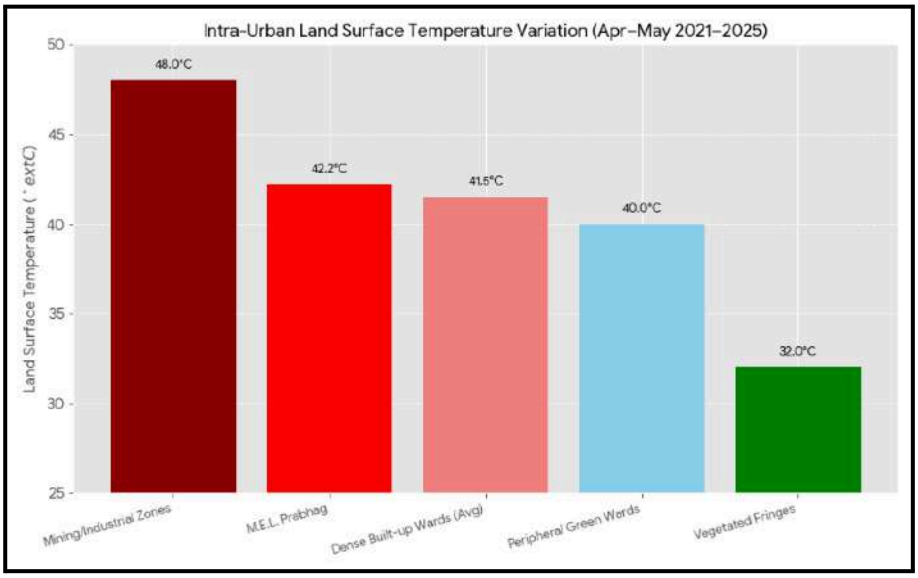


Figure 5 : Intra-urban LST by variation (Apr-May 2021-25)

Table 1 : LST by land uses (Apr-May 2021-25)

Land types	Avg LST (°C)	Example Ward	Characteristics
Mining/Industrial	42.2	M.E.L. Prabhag	Highest heat exposure, industrial emissions
Dense Built-up	41.5	Babu Peth, Vitthal Mandir	Compact cores, low vegetation
Compact Core	40.8	Jatpura, Vivek Nagar	Old urban fabric, dense settlement
Peripheral Green	39.2	Dego Tukum	Lower density, more vegetation

2) Seasonal Comfort Patterns

Summer (March–May): Temperature - 28–39 °C; frequent peak daytime overheating; Humidity - Low, around 40–45% (dry heat dominant); Wind - Predominantly southerly winds; moderate speeds, limited cooling effectiveness; Radiation- Very high global solar radiation (~900–1100 W/m²); clear skies dominate

Monsoon (June–September): Temperature - Moderate, typically 27–31 °C; Humidity - High, approximately 75–85%; Wind - Predominantly westerly winds; consistent airflow supports ventilation; Radiation - Reduced global radiation due to cloud cover; diffuse radiation dominant

Post-Monsoon (September–November): Temperature - Stabilized, averaging 26–28 °C; cooler nights (16–18 °C); Humidity - Moderate, around 55–65%; Wind - Variable winds with reduced intensity compared to monsoon; Radiation - Moderate solar radiation; balanced direct and diffuse components

(November–February): Temperature - Comfortable daytime range of 22–28 °C; night minima near 14–16 °C; Humidity- Lower, around 40–55%; Wind - Generally calm to light winds; minimal wind-driven cooling; Radiation - Moderate daytime solar radiation; clear skies support passive heat gain

Heat vulnerability in Chandrapur disproportionately affects low-income communities, outdoor workers, informal settlements, and densely built urban pockets. The convergence of industrial heat sources, mining expansion, limited green cover, and compact high-density settlements create acute exposure risks that demand targeted cooling interventions and climate-responsive urban planning.

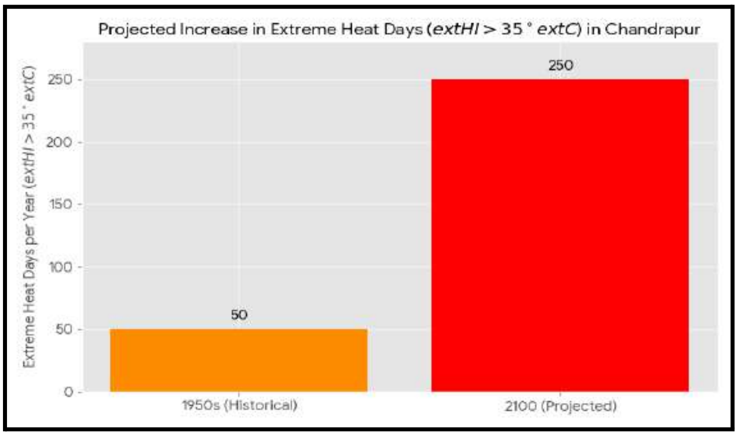


Figure 6 : Projected Increase in Extreme Heat Days

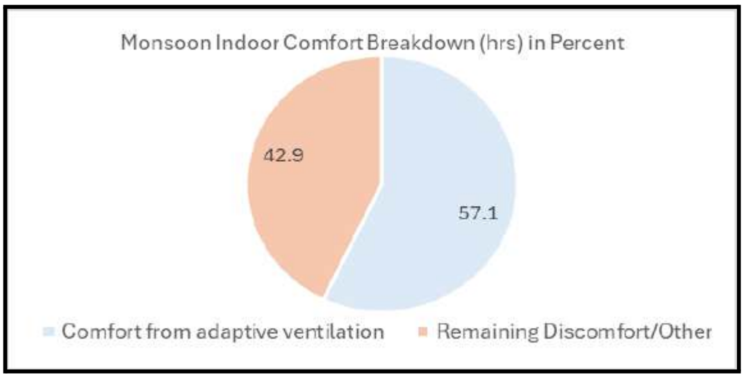


Figure 7 : Monsoon Indoor Comfort Breakdown (hours)

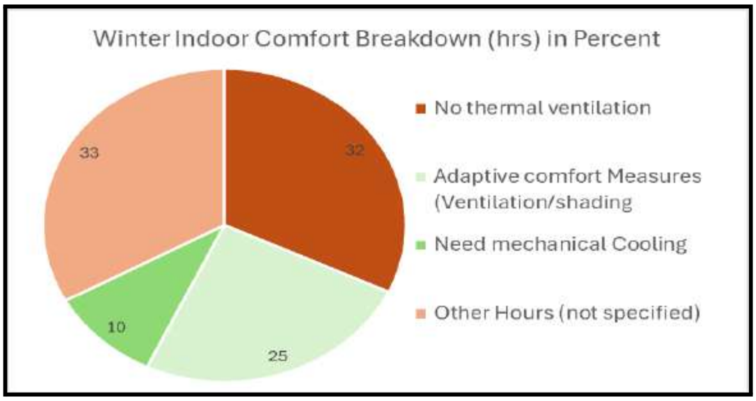


Figure 8 : Winter Indoor Comfort Breakdown (hours)

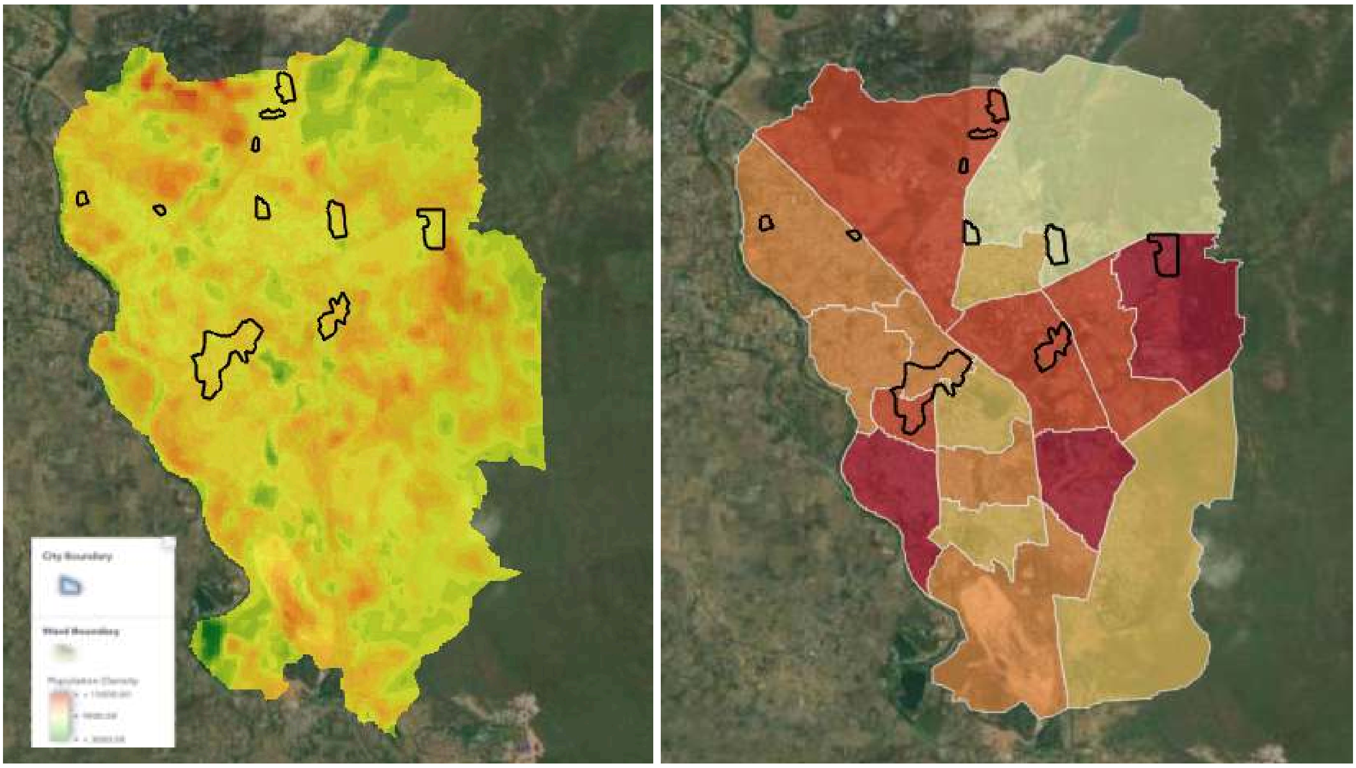


Figure 9 : Population density in Chandrapur and ward boundaries with informal settlements.

B. Understanding Informal Settlements in Chandrapur

Chandrapur Municipal Corporation (CMC) has identified 39 informal settlements across its jurisdiction. These include notified slums, non-notified bastis, and occupational enclaves such as Safai Karmachari colonies serving the city's essential sanitation infrastructure. 33% of the total population of Chandrapur lives in slums.

Classification	Number of Settlements	Recognition Status
Notified Slums	24	Officially listed in ULB records
Non-notified Settlements	12	Functionally present, legally unrecognized

Safai Karmachari Clusters	9 (within above)	Often partially notified or regularized

These settlements are concentrated in wards such as Ghutkala Talav, Panchshil Nagar, Rehmat Nagar, Babupeth, Bhivapeth, and Gouri Nagar, and are generally situated along the nalas and railway lines, on low-lying, flood-prone terrain and adjacent to industrial zones or dumping grounds.

Spatial analysis reveals that these zones exhibit higher surface temperatures, lower vegetation cover, and poor connectivity to formal infrastructure grids, intensifying thermal and health risks.

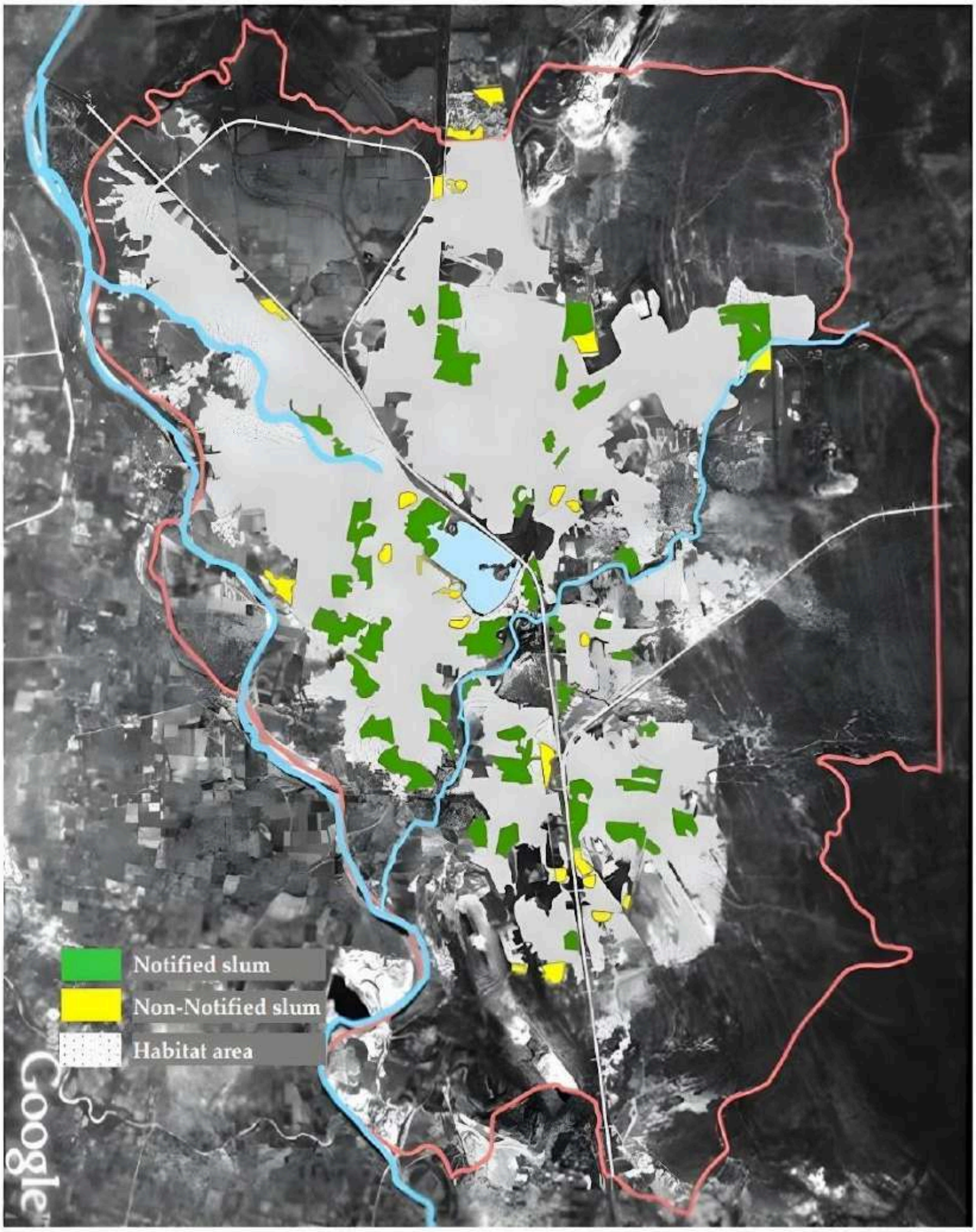


Figure 10 : Spatial analysis of Informal Settlements

Source : CEPT University, 2011

2. Enhancing Thermal Comfort and Renewable Energy Integration in Low-Income Settlements

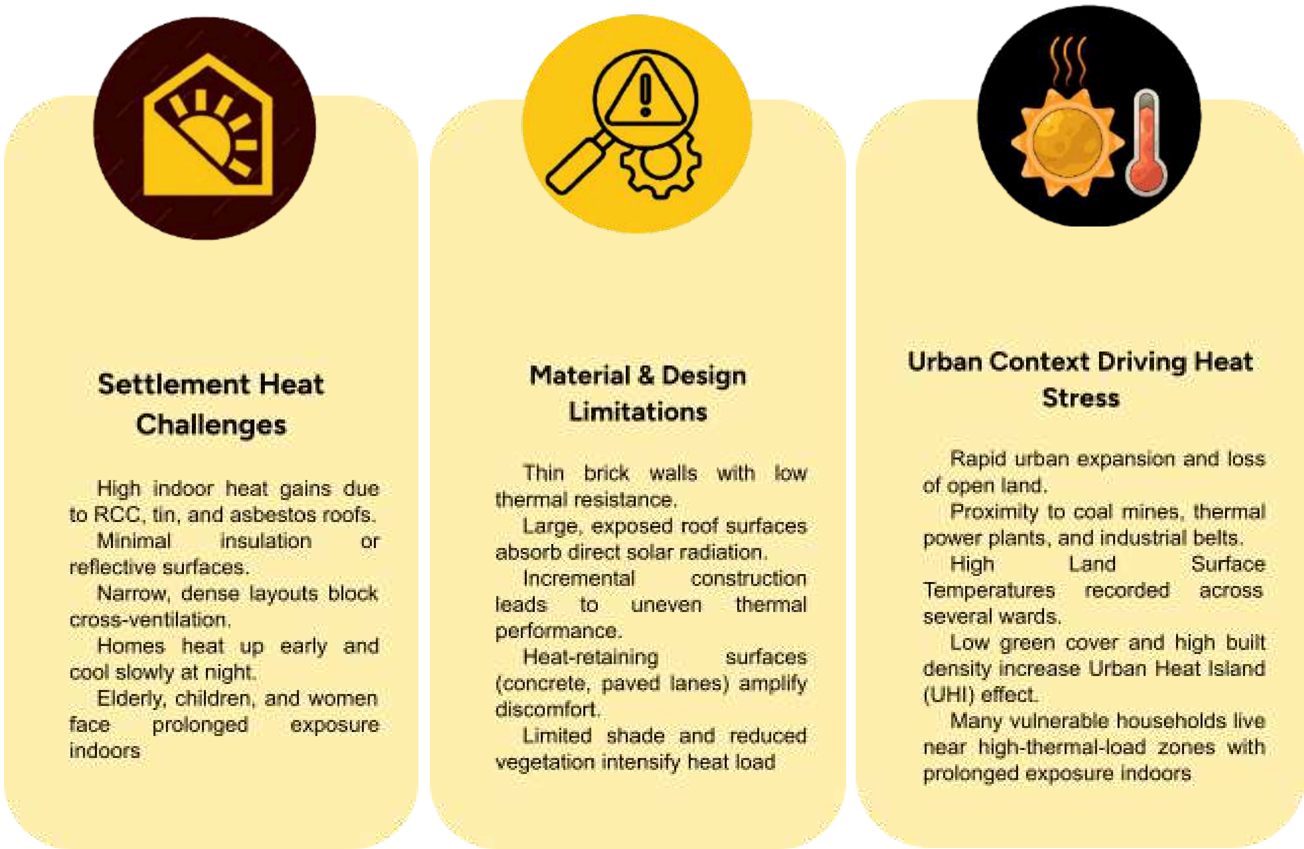


Figure 11 : Need for Retrofitting in Chandrapur

Why Cooling Retrofits Matter?

Low-cost, high-impact cooling without increasing electricity use.
Immediate reduction in heat exposure for vulnerable households.
Feasible for incremental, self-built homes
Supports municipal and state Heat Action Plans
Reduces long-term dependence on mechanical cooling

A. Cooling Strategies Recommended for Chandrapur

The design intent behind recommending cooling strategies for Chandrapur is to reduce solar heat gain, enhance passive ventilation, and stabilize indoor thermal conditions through cost-effective and locally adaptable solutions. These strategies respond to the Chandrapur low-wind, high-radiation context, drawing upon vernacular construction wisdom while being guided by measurable thermal performance benchmarks validated through both regional studies and global precedents. Collectively, they establish a technically robust, economically practical, and socially inclusive cooling framework suited for informal and low-rise housing typologies.

Table 2: Passive Cooling Retrofit Strategies for Each Housing Typology in Chandrapur Based on Built Form

Building Component	Kutcha	Semi-Pucca	Pucca	Mangalore
Roof	Lime-based SRI coating, Aluminium bubble wrap insulation, green net or bamboo overlay shade.	Lime-based SRI coating, green net or bamboo overlay shade, Solar-powered roof exhaust fan.	Pre-engineered cool roof panels, EPS insulation boards under slab, White tile or reflective membrane overlay.	Ceiling void insulation(jute/wool), Bamboo-mat ventilated ceiling, Lime-wash on inner tile surface.
Wall	Lime plaster on exterior, Mud + cow dung render (traditional), Whitewash for solar reflection.	External lime plaster with whitewash, Partial cavity inserts with EPS boards, Exterior jute cloth cladding (removable).	External lime-cement rendering, External ventilated cladding (e.g., PVC), Paint with high-SRI white coating.	Lime-clay plaster, Brick + bamboo panel cladding (interior), White exterior paint.
Opening	Shaded openings, Enlarged ventilated windows, Shaded Jali openings, Bamboo screen window flaps.	Operable louver vents above windows, Solar chimney for venting.	Enlarged ventilated windows, Window overhangs or mini-chhajjas, Adjustable exterior louvered shutters.	Top-light Jali vents, Shaded high clerestory windows, Wooden adjustable shutters with mesh.

Table 3 : Passive Cooling Roof Retrofit Strategies

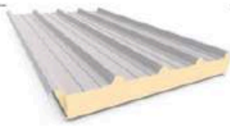
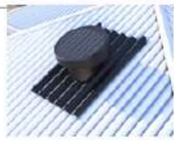
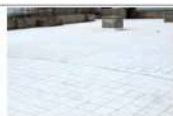
Building Component	Kutcha	Semi-Pucca	Pucca	Mangalore
Roof	 Lime-based SRI coating,	 Terracotta retrofit	 Pre-engineered cool roof panels	 Ceiling void insulation(jute/wool).
	 Aluminium bubble wrap insulation	 Green net or bamboo overlay shade,	 EPS insulation boards	 Bamboo-mat ventilated ceiling
	 Green net	 Solar-powered roof exhaust fan	 White tile or Cool Radiant tile	 Lime-wash on inner tile surface.

Table 4 : Passive Cooling wall Retrofit Strategies

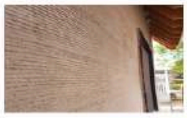
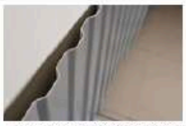
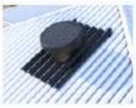
Building Component	Kutcha	Semi-Pucca	Pucca	Mangalore
Wall	 Lime plaster on exterior	 External lime plaster with whitewash	 External lime-cement rendering	 Lime-clay plaster
	 Mud + cow dung render (traditional)	 Partial cavity insert with EPS boards	 External ventilated cladding	 White exterior paint
	 SRI Paint	 Exterior jute cloth Shading	 Bamboo curtain	 Brick + bamboo panel cladding (interior)

Table 5 : Passive Cooling Openings Retrofit Strategies

Building Component	Kutcha	Semi-Pucca	Pucca	Mangalore
Opening	 Enlarged ventilated windows	 Window overhangs	 Terracotta Coolant evaporative system	 Top-light jali vents
	 Shaded pivot jaali openings	 Solar-powered exhaust fan	 Evaporative cooling with - Khus mats	 Wooden adjustable shutters with mesh.
	 Bamboo screen window flaps	 Window Fins	 Adjustable exterior louvered shutters	 Shaded high clerestory windows

The research uses five comprehensive indices to evaluate cooling interventions across different critical dimensions. The Climatic Suitability Index assesses how well each intervention responds to local environmental conditions, specifically examining ambient temperature patterns and solar radiation intensity. This determines whether a cooling solution is genuinely appropriate for the region's unique climate or likely to underperform in actual conditions.

The Thermal Performance Index measures the actual cooling effectiveness through three key parameters. It evaluates the temperature difference between indoor and outdoor spaces, the mean radiant temperature that occupants experience, and the thermal lag that indicates how long the intervention maintains comfortable conditions after external temperatures rise. These measurements together reveal the true cooling capability of each solution. The Material Sustainability Index examines the environmental footprint by considering the embodied energy required for production and transportation alongside local material availability. This ensures interventions use resources efficiently and favor locally abundant materials over those requiring extensive processing or long-distance shipping.

The Implementation Feasibility Index addresses practical deployment challenges by evaluating both the financial investment required and the labor complexity involved. Solutions demanding specialized skills or substantial budgets score lower than those implementable with local expertise and modest resources, making this index crucial for widespread adoption potential. The Social Adoption Index recognizes that technical success means nothing without community acceptance. It captures user satisfaction, aesthetic preferences, and cultural compatibility, ensuring recommended solutions align with how people actually live and what their traditions consider appropriate. This prevents technically sound interventions from failing due to social rejection or cultural incompatibility.

B. Stakeholder Engagements

1) Stakeholder Typology and Roles

Stakeholders are grouped into four strategic categories based on influence, operational involvement, and accountability:

Table 6 : Stakeholder Typology and Roles

Stakeholder Group	Key Actors	Roles and Responsibilities
Municipal Governance	Chandrapur Municipal Corporation (CMC) Ward Officers Health Department	- Facilitate site access and permissions- Policy integration into Heat Action Plan- Liaison with District Health Officer for ASHA coordination- Participate in Steering Committee
Community Anchors	ASHA Workers, Mahila Mandals, Community Heat Committees (CHC)	- Household-level awareness, supervision, and feedback- Disseminate IEC materials- Monitor implementation and reinforce behavior change- Act as social bridges with implementing team
Technical and Delivery Partners	AKAH India field and engineering teams, Urban heat advisory expert, Local contractors and vendors	- Conduct simulations, feasibility assessments- Procure and install technologies- Train community groups and monitor thermal data

2) Listening Workshop

A participatory Listening Workshop was conducted in informal settlements of Chandrapur to document residents' living experiences of seasonal stress particularly extreme heat, water scarcity, flooding, and winter discomfort. It brought together 30 members such as Safai Karamcharis, women, the elderly, and youth. The workshop aimed to identify community-specific vulnerabilities; understand coping practices across summer, monsoon, and winter; and ensure that retrofit solutions reflect real household needs and constraints. Participants described issues in their own language, allowing spontaneous storytelling and intergenerational knowledge-sharing. This allowed technical data collection to be grounded in community realities.

Key Seasonal Insights

Figure 12 : Seasonal Insights

a) Resident Voices

"Garmi mein bachchon ko daane nikalte hain, bukhaar aur chakkar lagta hai."
"Bijli ka bill bahut badh jata hai, par garmi kam nahi hoti."

The Listening Workshop generated a visual, community-authored database of seasonal challenges, directly informing technical diagnostics and retrofit design. Insights from residents guided the selection of the 10 representative houses, validated modelling results, and shaped the choice of feasible passive cooling strategies such as cool roofs, insulation, improved ventilation, and shading. The process strengthened trust and reinforced that resilient housing solutions must be co-designed with communities, not imposed upon them.

b) Key Objectives

- Raise awareness of extreme heat impacts on residents, children, elderly, and women.
- Introduce cooling solutions like SRI paint, lime plaster, EPS insulation, and passive ventilation.
- Promote energy-saving appliances (solar cooler, rooftop solar, BLDC fans, exhaust fans).
- Facilitate hands-on demos to increase trust and ease of understanding.
- Strengthen community–vendor links and improve last-mile access.
- Activate frontline workers (ASHA, sanitary union) as community influencers.

C. Cooling Strategies Recommended for Low-Income Housing

The study focuses on ground (G) and ground-plus-one (G+1) houses typical of Chandrapur's low-income settlements, generally 300–500 sq. ft in area and accommodating 4–6 occupants. The analysis covers the three predominant roof types-RCC, GI/metal, and asbestos-as they contribute most to heat gain and represent the city's dominant construction patterns.

Considering these dwelling categories, roof materials, and settlement conditions, 10 representative houses have been selected for detailed retrofit assessment and performance evaluation.

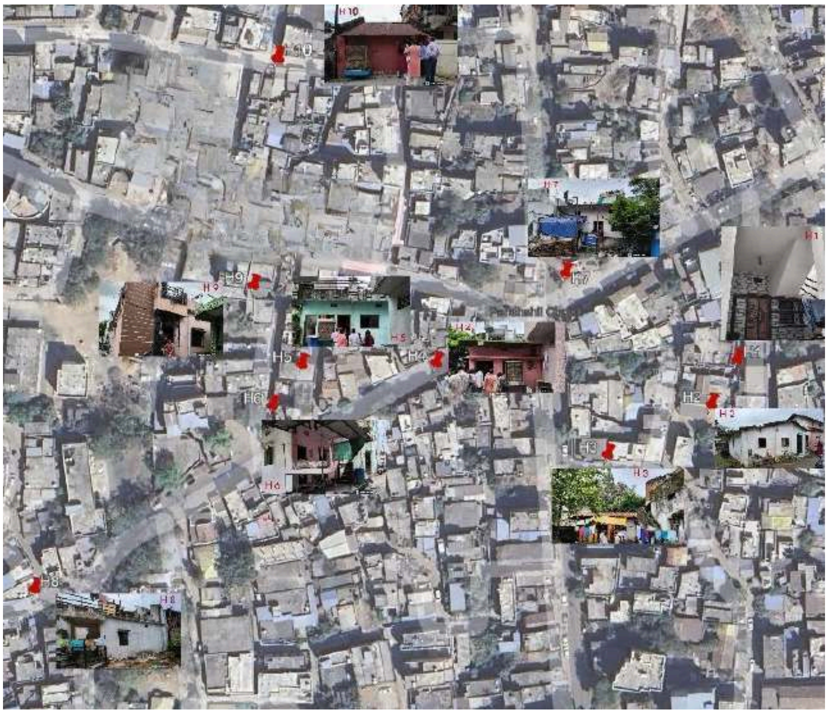


Figure 14 : Selected Houses for Cooling Strategies Recommendations

Objectives of the Retrofit Analysis

Building upon the identified need for improving thermal comfort in low-income housing, this study aims to systematically evaluate existing indoor conditions and propose feasible retrofit strategies suited to the local context of Chandrapur. The analysis focuses on enhancing comfort through passive means while integrating opportunities for renewable energy use.

The specific objectives of the retrofit analysis are as follows:

- To analyze the existing indoor comfort conditions of selected dwellings through on-site measurements and occupant surveys, and to evaluate their performance against the IMAC adaptive comfort standards.
- To develop and validate Design Builder models of the existing dwellings using field measurement data, and to assess annual thermal comfort performance by comparing results with IMAC and ASHRAE 55 standards.
- To identify suitable roof retrofit strategies for each house and assess their potential in improving indoor thermal comfort.
- To determine effective wall retrofit strategies and evaluate their contribution to reducing indoor heat gain and enhancing comfort.
- To examine combined roof and wall interventions, identify configurations that achieve a notable reduction in indoor temperature, particularly during peak summer hours.
- To suggest energy reduction measures through the integration of solar energy systems and energy-efficient appliances, promoting long-term sustainability and resilience in low-income housing.

1) Methodology Adopted for Analysis

The research on retrofit analysis focused on ten representative low-income dwellings in Chandrapur to understand and improve indoor thermal comfort through an evidence-based approach. Field investigations were carried out to record on-site environmental conditions, and the existing comfort levels were assessed in relation to the IMAC adaptive comfort standards. The houses were then modeled in Design Builder software as realistic as possible, and the simulated values were compared with field data for validation.

a) Modelling and Validation in Design Builder Software

The selected houses were modelled in Design Builder along with their context. Simulations were run for the same day as that of the field measurements i.e., 24th and 25th August 2025. Then, the simulated measurements were compared with the field measurements for validating the model parameters for all 10 houses. The accuracy of the computer model is verified through a statistical measure called the R value, which indicates how closely the simulated building matches the actual physical building's behavior. The validation process continues iteratively until the model achieves an R value of 0.7 or higher, which researchers have established as the threshold for significant correlation. This benchmark ensures that digital representation reliably mirrors real-world conditions, as demonstrated in Figure 1. Once this level of accuracy is achieved, the validated model can be confidently used for running simulations, knowing that its predictions will closely reflect what would actually occur in the genuine environmental setting. This validation step is essential because it transforms the computer model from a theoretical approximation into a trustworthy tool that captures the true thermal behavior and environmental interactions of the real building.

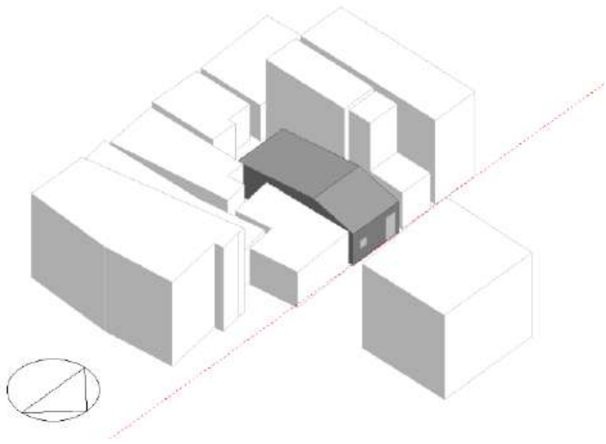


Table 7 : Design Builder model of the house along with context

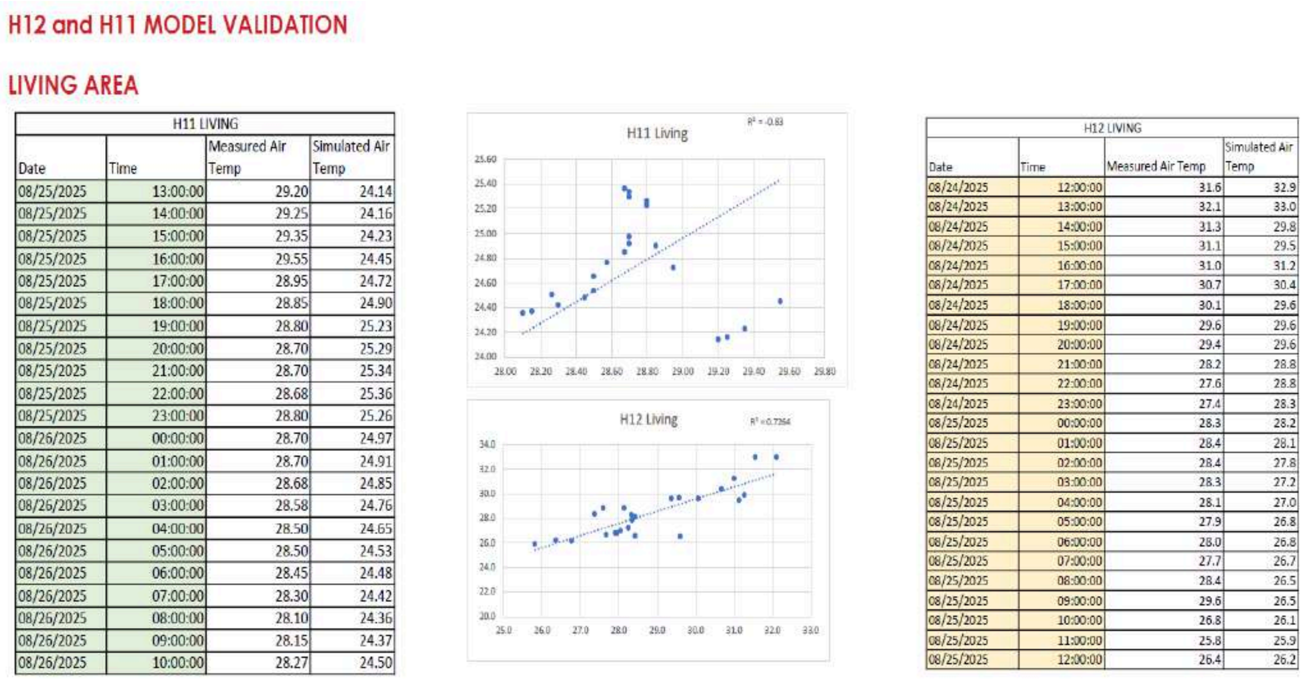
BASE CASE - UNIT H10		
Wall (Exterior) Brick masonry with plaster (base case, uninsulated)		
Parameter (DB / Energy Plus field)	Base-case value	Source
Construction name	WALL_230BRICK_PLASTER	
Layer 1 (outside) material	12 mm cement plaster	IES VE System Material DB lists "Cement Plaster" properties. (help.iesve.com)
Thickness	0.012 m	Standard plaster thickness (paired with IES material). (help.iesve.com)
Conductivity (k)	0.72 W/m·K	IES VE Table 6. (help.iesve.com)
Density (ρ)	1860 kg/m³	IES VE Table 6. (help.iesve.com)
Specific heat (cp)	800 J/kg·K	IES VE Table 6. (help.iesve.com)
Layer 2 (core) material	Burnt clay brick (solid)	Indian brick ranges + exemplar values below. (BEEP Website, bmtpc.org)

Thickness	0.230 m	Typical 9-inch wall; common for LIG houses. (Use your measured thickness if available.)
Conductivity (k)	0.81 W/m·K	Within Indian ranges (0.38–1.12). Example value ~0.81 reported for fired clay bricks. (BEEP Website, SSRN)
Density (ρ)	1700 kg/m³	Typical brickwork density listing (brickwork outer leaf). (mrsphysics.co.uk)
Specific heat (cp)	800–840 J/kg·K (use 840)	Typical for brickwork/plaster datasets. (mrsphysics.co.uk)
Layer 3 (inside) material	12 mm cement plaster	Same as Layer 1. (help.iesve.com)
Long-wave emissivity (thermal absorptance)	0.9	Typical opaque surface value (EnergyPlus conventions). (bigladdersoftware.com)
Solar absorptance (αs)	0.65 (medium brick/plaster paint)	IES VE Table 14: bricks range 0.25–0.9; 0.65 ≈ medium/dark. (help.iesve.com)
Visible absorptance	0.60–0.65 (match αs)	Aligns with medium tone finishes. (help.iesve.com)
Outside/Inside film coefficients	Use Energy Plus default algorithms (TARP/Adaptive) rather than fixed R	Energy Plus calculates film coefficients dynamically by surface type & conditions. (bigladdersoftware.com)
Roof Corrugated galvanized steel ("tin"), basecase		
DB / Energy Plus field	Base-case value	Source
Construction	ROOF_CGI_BARE	
Layer 1 (outside→inside)	Steel sheet (galvanized)	Material properties per IES table. (help.iesve.com)
Thickness	0.0005 m (0.5 mm typical CGI)	Indian product specs show 0.5–1.0 mm sheets. (ttandsons.in, manmohanroofing.com)
Conductivity (k)	50 W/m·K	IES System Material DB (steel). (help.iesve.com)
Density (ρ)	7800 kg/m³	IES System Material DB (steel). (help.iesve.com)

Specific heat (cp)	480 J/kg·K	IES System Material DB (steel). (help.iesve.com)
Long-wave emissivity (thermal absorptance)**	0.23 (new, shiny GI) → 0.85–0.90 (weathered)	Emissivity of galvanized steel: new vs. aged. Use aged value if roof is not brand-new. (Engineering ToolBox)
Solar absorptance (αs)	0.65 (galvanized iron)	IES Table 14 lists “Galvanised iron = 0.65”; EngineeringToolbox shows 0.64 new, up to 0.92 dirty. (help.iesve.com, Engineering ToolBox)
Film coefficients	Use EnergyPlus dynamic films (TARP/Adaptive)	Don’t hardcode Rsi/Rso; let EP compute by surface/conditions. (EnergyPlus)

After validation of each house model, the annual thermal performances of all 12 houses were simulated and were compared to IMAC and ASHRAE 55 benchmarks. Further, the thermal performance during critical summer months and total annual discomfort hours were assessed.

Table 8 : Design Builder Inputs for Base case simulations



H11 LIVING			
Date	Time	Measured Air Temp	Simulated Air Temp
08/25/2025	13:00:00	29.20	24.14
08/25/2025	14:00:00	29.25	24.16
08/25/2025	15:00:00	29.35	24.23
08/25/2025	16:00:00	29.55	24.45
08/25/2025	17:00:00	28.95	24.72
08/25/2025	18:00:00	28.85	24.90
08/25/2025	19:00:00	28.80	25.23
08/25/2025	20:00:00	28.70	25.29
08/25/2025	21:00:00	28.70	25.34
08/25/2025	22:00:00	28.68	25.36
08/25/2025	23:00:00	28.80	25.26
08/26/2025	00:00:00	28.70	24.97
08/26/2025	01:00:00	28.70	24.91
08/26/2025	02:00:00	28.68	24.85
08/26/2025	03:00:00	28.58	24.76
08/26/2025	04:00:00	28.50	24.65
08/26/2025	05:00:00	28.50	24.53
08/26/2025	06:00:00	28.45	24.48
08/26/2025	07:00:00	28.30	24.42
08/26/2025	08:00:00	28.10	24.36
08/26/2025	09:00:00	28.15	24.37
08/26/2025	10:00:00	28.27	24.50

H12 LIVING			
Date	Time	Measured Air Temp	Simulated Air Temp
08/24/2025	12:00:00	31.6	32.9
08/24/2025	13:00:00	32.1	33.0
08/24/2025	14:00:00	31.3	29.8
08/24/2025	15:00:00	31.1	29.5
08/24/2025	16:00:00	31.0	31.2
08/24/2025	17:00:00	30.7	30.4
08/24/2025	18:00:00	30.1	29.6
08/24/2025	19:00:00	29.6	29.6
08/24/2025	20:00:00	29.4	29.6
08/24/2025	21:00:00	28.2	28.8
08/24/2025	22:00:00	27.6	28.8
08/24/2025	23:00:00	27.4	28.3
08/25/2025	00:00:00	28.3	28.2
08/25/2025	01:00:00	28.4	28.1
08/25/2025	02:00:00	28.4	27.8
08/25/2025	03:00:00	28.3	27.2
08/25/2025	04:00:00	28.1	27.0
08/25/2025	05:00:00	27.9	26.8
08/25/2025	06:00:00	28.0	26.8
08/25/2025	07:00:00	27.7	26.7
08/25/2025	08:00:00	28.4	26.5
08/25/2025	09:00:00	29.6	26.5
08/25/2025	10:00:00	26.8	26.1
08/25/2025	11:00:00	25.8	25.9
08/25/2025	12:00:00	26.4	26.2

b) Simulated Vs Measured Air Temperatures

Various roof and wall retrofit strategies for each of the selected houses were analyzed to determine their effectiveness in reducing the indoor temperatures and improving comfort levels during peak summer periods. Table 1 shows the identified roof and strategies that are suitable for hot and Semi-arid climate. The retrofits suitable for each house have been chosen based on the feasibility on site, the site context, disruption on site, cost and occupants’ acceptance. According to the above aspects, 2-3 retrofit options for roof and wall were simulated for each house in Design Builder to identify the optimized retrofit options that enhanced indoor thermal comfort.

Table 9 : Proposed Roof and Wall Retrofit Strategies

Roof Retrofit strategies	Wall Retrofit strategies
SRI roof coating	SRI wall coating
SRI + EPS board insulation	SRI + Vermiculite brick
Cool roof tiles	Lime wash
Mineral Wool Insulation	SRI + tetra Pak insulation
SRI + Mineral Wool Insulation	Bamboo Insulated Wall
SRI + tetra Pak board insulation	Coir Board Insulated Wall
Bamboo Insulated GI Roof	Solar Film Glazing + Tetra Pak Wall Insulation
China Mosaic Tile on RCC Roof	Shading Device + Solar Film + Tetra Pak Wall Insulation
Lime Concrete Retrofitted Roof	EPS wall
Lime Concrete + Mangalore Tile Roof	lime wash + lime plaster
Alu foil + tetra Pak insulation	EPS+SRI
EPS Insulation	Foam Polyurethane Insulation
Foam Polyurethane Insulation + SRI	CASI blocks + SRI
XPS Insulation board	MUD PLASTER
Reflective foil	
Aluminium foil	
Reflective + alu foil	

D. Detailed Analysis of Selected Houses

Table 10 : Detailed Retrofit Analysis of Selected Houses

Parameter	House 1	House 2	House 3	House 4	House 5
House Type	RCC	Asbestos Sheet Roof	Tin Sheet Roof	RCC Roof	RCC Roof
Base Discomfort (%)	86%	72%	84%	35.46% (House 4 base case)	78.48%
Best Roof Retrofit	SRI Roof Coating (~2°C reduction)	SRI + Mineral Wool (≈4.3°C reduction)	SRI + Mineral Wool (~4.3°C reduction)	China Mosaic Tile Roof (~3°C reduction)	SRI Painted Roof (~10.15°C reduction)
Best Wall Retrofit	SRI Wall Coating (~0.5–1°C reduction)	Wall upgrades showed marginal impact (≤1.8°C); not recommended for main implementation	Wall retrofits offer marginal benefit (~0.4°C)	Lime Plaster + Lime Wash (~5.4°C reduction) (same wall set used for this cluster typology)	Wall interventions provided marginal impact (~0.4°C); not a priority
Combined Impact	~15% reduction in peak overheating; comfort improves from 86% discomfort to ~69–82%	Discomfort reduces from 72% → ~32% with SRI + Mineral Wool (≈40% improvement)	Discomfort reduces from 84% → ~42% (~40–50% improvement)	Peak discomfort drops from ~35% → ~7–10% (~25–30% comfort improvement)	Discomfort reduces from 78% → ~50–55% (~30% improv
Cost Band	Low (roof), Low (wall)	Medium–High (mineral wool)	Medium–High (miner wool)	Medium (roof), Low (wall)	Low (roof)
Parameter	**House 6**	**House 7**	**House 8**	**House 9**	**Details**
House Type	RCC Roof (South-facing)	RCC Roof	Tin / Lightweight Roof	RCC Roof	Metal / Tin Roof
Base Discomfort (%)	(awaiting exact value from file can insert once shared)	High (typical RCC range: 75–85%) *(matches Houses 1, 5, 9 RCC patterns)*	High (typical tin range: 80–90%)	High (typical RCC range: 75–85%)	Very High (typical tin range: 85–90%)
Best Roof Retrofit	China Mosaic Tile Roof (~3–5°C reduction)	China Mosaic Tile Roof (~3–4°C reduction)	SRI Paint (~2–3°C reduction)	Cool Roof Tile (~3–4°C reduction)	SRI Roof Paint (~2–3°C reduction)
Best Wall Retrofit	PUF Board on South Wall (~2.5–3°C reduction)	PUF Board + 12mm Tetrapak Insulation (South-facing wall) *(~2–2.5°C reduction on exposed façade)*	Lime Plaster + Lime Wash (~2–2.5°C reduction)	Lime Plaster + Lime Wash (~5°C reduction on sun-exposed walls)	Not recommended / minimal impact
Combined Impact	12 mm Tetra Pak Underdeck Insulation (~1–1.5°C)	~30–40% improvement in comfort (major gains due to solar-exposed south wall + reflective roof)	~25–35% improvement in comfort	~30–40% improvement in thermal comfort	~15–20% improvement in comfort (roof-only)
Cost Band	Significant reduction in both peak and evening heat; ~30–40% improvement in comfort	Medium (roof), Low–Medium (wall)	Low (roof), Low (wall)	Medium (roof tile), Low (wall)	Low

E. Renewable Energy and Energy-Efficient Retrofit Interventions

The renewable energy and energy-efficient retrofit intervention was developed to complement passive cooling strategies in low-income housing settlements in Chandrapur, responding to extreme heat exposure, unreliable electricity supply, and affordability constraints. The approach prioritizes decentralized, low-capacity renewable solutions that improve thermal comfort and reduce electricity dependence while remaining technically feasible, socially acceptable, and financially accessible for vulnerable households.

Energy demand in informal settlements is modest but essential, primarily covering lighting, fan operation, ventilation, mobile charging, and heat-related comfort needs during summer months. Frequent power outages during peak heat periods exacerbate indoor discomfort and health risks. Integrating renewable energy with passive cooling enables households to meet these critical needs while reducing grid dependence and energy costs.

1) Technology Package and Design Rationale

Based on housing typologies, user behavior patterns, and high solar availability (approximately 250–300 sunny days annually), a modular technology package was identified that can be adopted incrementally:

- DC Solar Home Kits (50–100 Wp): Low-voltage systems for lighting and small appliances that avoid inverter losses and are suitable for compact dwellings.
- Solar Home Systems (100–200 Wp) with Battery Storage: Support BLDC fans, lights, and essential appliances during power outages, improving night-time thermal comfort and energy reliability.
- BLDC Fans: Consume 50–60% less energy than conventional fans and function efficiently on small battery systems.
- Solar Exhaust Fans and Window Ventilators: Enhance indoor airflow by removing hot air during peak hours, particularly effective in kitchens and bathrooms with minimal installation requirements.
- Solar-Powered Evaporative Coolers: Appropriate for hot-dry conditions, providing 6–10°C temperature reduction while consuming only 150–200 W.
- Community-Level Rooftop PV (1–3 kWp): Intended for shared facilities to support lighting, fans, water pumping, and essential services.

All technologies were screened against criteria including structural capacity, shading conditions, ease of maintenance, affordability, and compatibility with household routines, ensuring alignment with local constraints and user capacities.

The implementation roadmap progresses through four structured phases beginning with renewable energy awareness campaigns and demand mapping through community engagement sessions, followed by vendor prequalification processes involving technical and service evaluations from multiple providers. The strategy then advances pilot installations in selected households across different housing typologies with comprehensive documentation of implementation experiences, culminating in policy recommendations for integration into local housing action plans and identification of financing mechanisms through national schemes and municipal budgets.

Monitoring and evaluation protocols track energy generation and consumption through solar controller data, assess comfort improvements via fan usage patterns, measure user satisfaction and willingness to invest in scaling up, and evaluate gender-specific impacts through focused discussions with women's groups. This comprehensive framework positions renewable energy as a viable pathway toward enhancing energy security and thermal comfort in Chandrapur's informal housing settlements.

3. Implementation of Cooling and Energy Efficient Measures

Before	After Implementation-cooling solutions	Electricity efficient appliances	Solar Installation
House 1			
			
Application	SRI paint	BLDC Fan + Window ventilator	-
House 2			
			
Application	SRI Paint	BLDC Fan	100v dc Solar Installation
House 3			
			
Application	SRI Paint+ Mineral wool	BLDC Fan + Window ventilator	
House 4			

			
Application	China Mosaic Lime wash+ Lime plaster	-	Solar Air Cooler (Evaporative)
House 5			
			
Application	SRI Paint	Heavy-Duty Solar Ventilation Exhausts (Single Metal Shell Fans)	100v dc Solar Installation
House 6			
			
Application	Cool roof tiles	BLDC Fan	100v dc Solar Installation
House 7			
			
Application	SRI Roof	-	100v dc Solar Installation
House 8			
			
Application	SRI Paint Lime wash+ Lime plaster	-	100v dc Solar Installation
House 9			

			
Application	Cool Roof tile Lime wash+ Lime plaster	BLDC Fan	Heavy-Duty Solar Ventilation Exhausts (Single Shell Fans)
House 10			
			
Application	SRI Paint	-	-

4. Policy Framework

Total roof area within Chandrapur city is approximately 22.5 million m², of which nearly 0.69 km² (690,000 m²) lies within informal and low-income settlements, the areas most exposed to heat stress and limited access to thermal comfort. These built-up clusters experience surface temperatures exceeding 50°C, with indoor temperatures in a few houses having corrugated GI sheet or asbestos sheets often 6–8°C higher than ambient shade levels. If 50% of the informal settlement roof area equivalent to 0.35 km² (350,000 m²) is retrofitted with cool or reflective roofing solutions by 2030, Chandrapur could reduce local heat exposure by up to 3–5°C, lower household indoor temperatures by 4°C on average and cut residential cooling energy demand by 20–25%. At a city scale, this transition would contribute to an estimated annual energy saving of 8–10 GWh, directly reducing electricity use during summer peak load periods and supporting CMC's renewable energy and heat resilience commitments.

A. Implementation Strategy

Chandrapur, like many Indian cities, operates under a Heat Action Plan (HAP) designed to reduce heat-related risks through early warning systems, public awareness, and emergency response measures. While the HAP outlines important steps such as communication strategies, health preparedness, and heat-vulnerability reduction, it currently lacks specific provisions for built-environment cooling measures, especially cool roofs one of the most cost-effective and scalable solutions for lowering indoor temperatures in low-income and high-exposure neighborhoods. At the national level, frameworks such as the India Cooling Action Plan (ICAP, 2019) and the National Mission on Sustainable Habitat encourage passive cooling and sustainable urban design, yet implementation at the municipal level remains uneven. Maharashtra's state policies, including energy-efficiency guidelines and solar promotion schemes, focus primarily on renewable energy adoption rather than building-level passive cooling. As a result, no dedicated municipal regulation or incentive structure currently mandates or promotes cool roofs in Chandrapur, leaving a critical policy gap in local heat resilience efforts.In this context, the proposed Chandrapur Cool Roof and Renewable Energy Guidelines 2025 have been developed as a policy framework to address this gap. These guidelines are intended to support the future integration of cool roof measures, renewable energy applications, and thermal comfort strategies into city planning processes, housing upgrade programs, and local climate resilience initiatives led by the Chandrapur Municipal Corporation (CMC).

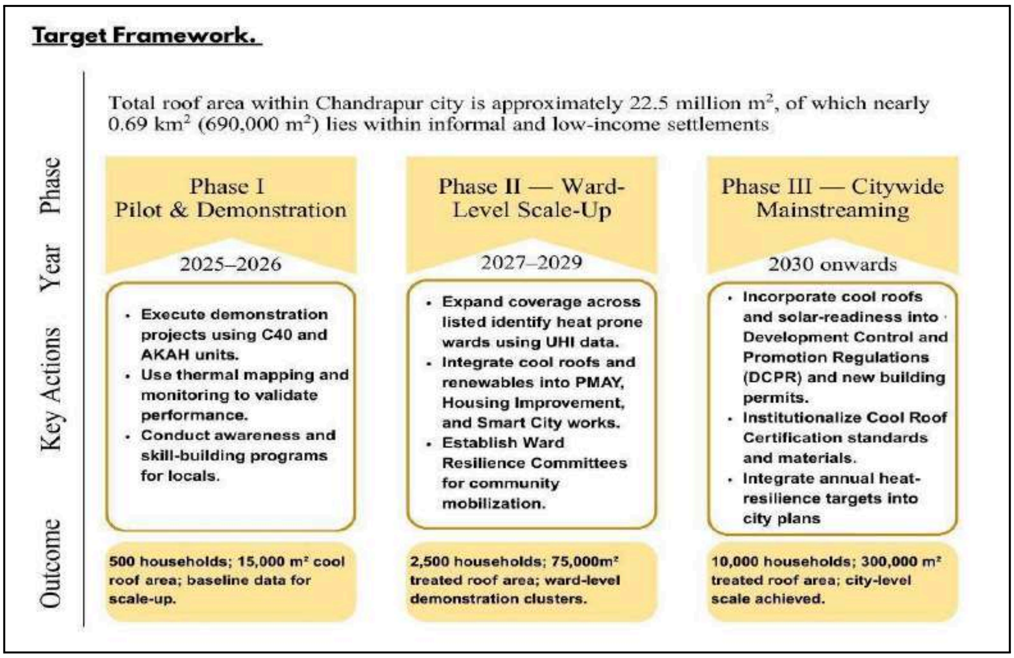


Figure 16 : Implementation Strategies and Target Framework

B. Technical Measures

1) Passive Cooling and Building Envelope Retrofitting

The following envelope-level retrofit strategies have been demonstrated across 10 representative homes in Chandrapur's informal and low-income settlements, addressing high heat gain through roofs and walls while improving year-round thermal comfort.

Table 11 : Roof-Level Measures

Roof Type	Recommended Measures	Cooling Impact	Key Technical Notes
RCC Roofs	• High SRI reflective coating (albedo ≥ 0.85) – Rs 45 / sqft • Expanded Polystyrene (EPS) insulation (50–70 mm) below SRI layer – Rs 130 / sqft • Cool roof tiles or China mosaic tile finish- Rs 140 / sqft	↓ Indoor temp by 2–5°C ↓ Discomfort hours by 30–50%	Reflects solar radiation and reduces conductive heat transfer. Most cost-effective and durable for dense settlements.
Corrugated GI sheet	• SRI paint (reflective coating, low emissivity) • Bamboo or mineral wool insulation layer (5–50 mm) - Rs 90 / sqft • Optional reflective foil or Tetra Pak insulation below sheet- - Rs 55 / sqft	↓ Peak indoor temp by 4–6°C ↓ roof heat gain by >40%.	Best for semi-pucca and metal structures.
Hybrid (RCC + GI Sheet) Roofs	• China mosaic tile finish on RCC section • SRI or bamboo insulation on GI portion	↓ Indoor temp by 3–4°C	Stabilizes diurnal temperature fluctuations; suited for mixed-material roofs.

2) Integrated Envelope Solutions

Combined envelope interventions (roof + wall) achieved overall indoor temperature reductions of 3–6°C, with up to 50% increase in comfort hours during peak summer. Best-performing combinations:

- RCC roof: SRI + EPS
- Metal roof: SRI + Mineral Wool
- Mixed roof: China Mosaic + Lime Wash
- South-facing walls: Lime Plaster + Tetra pak Panels

3) Renewable Energy Integration

Each retrofitted home integrates small-scale solar and energy-efficient technologies to enhance energy security and ventilation.

Table 12 : Integration for Renewable Energy

System	Specification	Benefit	Typical Cost Range
Solar Home Kits (100 Wp)	PV panel + battery + LED + BLDC fan	45–60% energy savings	₹10,000–₹15,000
Solar Exhaust Fans (10–25 Wp)	DC 12V exhaust fan (ABS body)	Removes trapped hot air; improves IAQ	₹5,000–₹7,000
Solar Evaporative Cooler (40–50 Wp)	12V DC motor + 20L water tank	Low-cost active cooling	₹8,000–₹12,000
BLDC Fans and LED Fixtures	High efficiency, low wattage	60–70% less power use	₹3000–₹5,000 per unit

C. Policy measures

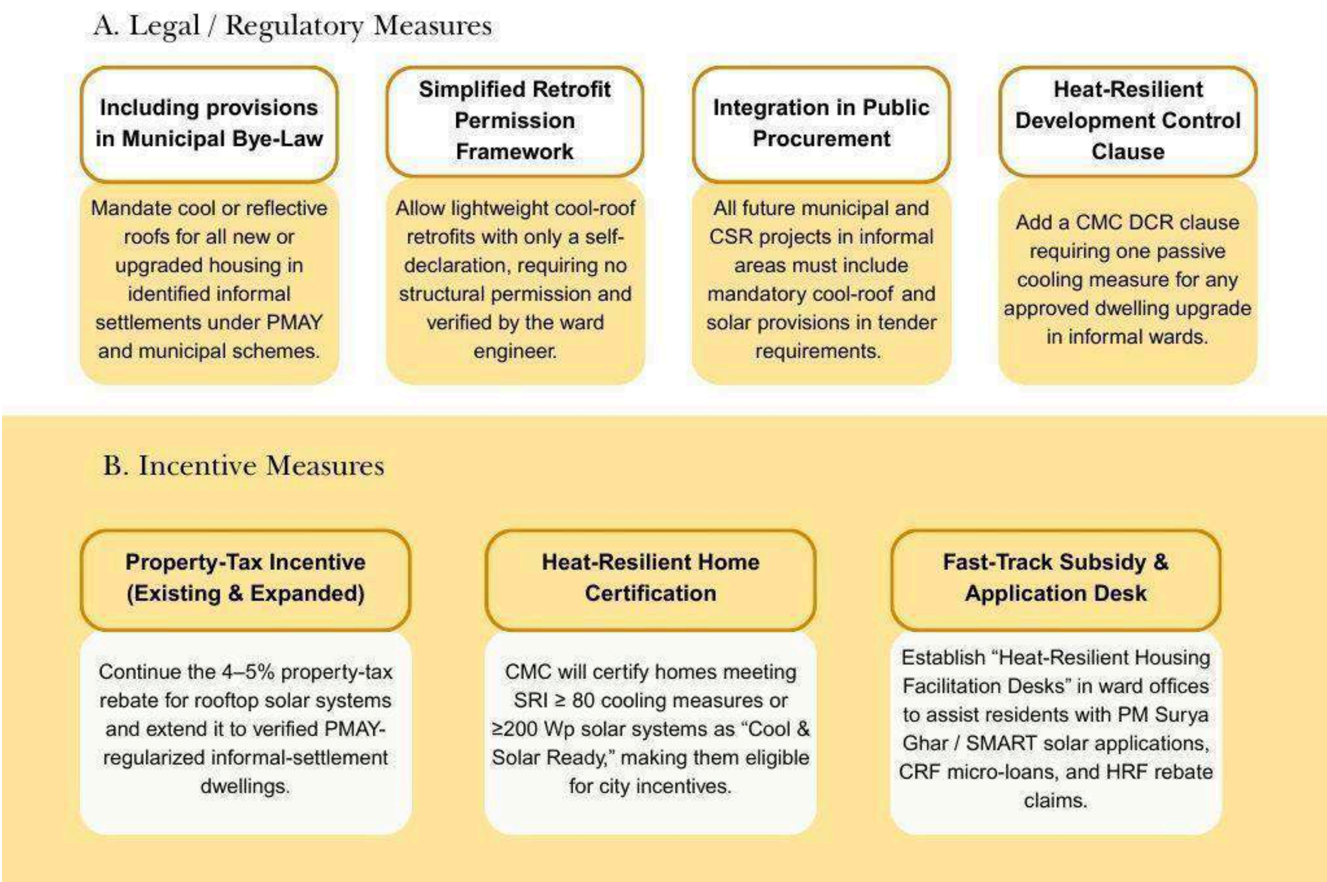


Figure 17: Policy Measure

D. Financial Frameworks

Table 13 : Financial Framework

Action / Instrument	Operational Steps for CMC	Funding Source / Scheme Linkage	Implementation Pathway
1. Cool-Roof & Passive Cooling Subsidy	• Identify 1,000 homes through ward-level surveys. • Empanel vendors with approved IS 17218 cool-roof coatings. • Include low-cost reflective paint and insulation under eligible PMAY "enhancement" works.	• PMAY-Urban (Beneficiary-Led Construction / Enhancement) ₹1.5 lakh per beneficiary assistance. • CSR contributions (e.g., WCL, ACC Cement, Tata Trusts) to co-finance material costs.	• Ward engineers certify eligible PMAY beneficiaries. • CSR partners provide materials; CMC verifies installation and links to PMAY enhancement reimbursement.
2. Rooftop Solar & Solar-Home Systems	• Establish Ward Facilitation Desks for residents to register solar applications. • Empanel MNRE-certified vendors for SHS and rooftop systems.	• MNRE PM Surya Ghar Scheme – Central Financial Assistance up to 40% for 1–3 kW residential rooftop systems. • MahaUrja / MSEDCL SMART Solar Scheme – State top-up subsidy (20–30%). • CMC Property-Tax Rebate (4–5%) – existing incentive.	• CMC aggregates household applications via MNRE portal. • Vendor installs after CFA approval; state subsidy credited by MSEDCL. • CMC applies property-tax rebate upon installation verification.

3. Community Cooling & Solar Infrastructure	• Retrofit existing community structures (Anganwadi's, schools, ward offices) with insulation, reflective roofs, and solar-powered ventilation.	• AMRUT 2.0 – Urban Resilience Component (MoHUA). • State Urban Development Funds for heat adaptation. • CSR partnerships for materials or full installation support.	• Propose "Community Cooling and Solar Infrastructure" as a sub-project in AMRUT Annual Action Plan. • CSR partners implement under MoU with CMC (branding and ESG benefits).
4. CSR / PPP "Adopt-a-Ward" Initiative	• Identify local industry partners. • Create MoUs for adopting 100 homes per ward.	• Corporate CSR under Schedule VII(b): Environment & Sustainability.	• Corporates directly procure and install approved cool-roof and solar kits through empanelled vendors. • CMC provides official certification, visibility, and recognition for participating firms.
5. Results-Based Finance / Carbon Credit Mechanism	• Install IoT loggers in pilot homes to track indoor temperature and energy savings. • Aggregate verified data for emission-reduction certification.	• Voluntary Carbon Markets • C40 Urban Cooling Finance & Performance-Based Grants.	• Aggregate verified projects (minimum 500–1,000 homes) as a micro carbon project. • Revenue from carbon credits (approx. ₹700–1,000 per t CO_2 saved) can finance additional household retrofits.

Market Deployment & Disbursement Mechanism

1. Standardized Kits & Pricing
    - Cool-Roof Kit: IS 17218 compliant, SRI ≥ 80, 4-coat system, cost ₹50,000–₹60,000 per roof.
    - Solar-Lite Kit: 200–300 Wp solar system for lighting and fans, ₹15,000–₹20,000 (after subsidy).
2. Vendor Empanelment
    - Open EOI for IS/MNRE-certified vendors (≥3 years' experience, 24-month warranty).
    - Vendors offer pre-approved kits with fixed pricing and documentation for subsidy claims.
3. Procurement & Payment Flow
    - Residents apply via Ward Facilitation Desk → Vendor installs → Subsidy and CFA processed via MNRE/MSEDCL → CMC verifies and applies tax rebate.
4. Quality Assurance
    - Geo-tagged pre/post photos, temperature verification (surface & indoor), and third-party audit before payment release.
5. Ease of Access
    - "Housing Mela" camps in informal settlements for on-spot subsidy registration and vendor selection.
    - Assistance for PM Surya Ghar, SMART Solar, and property-tax rebate applications.

E. Governance framework

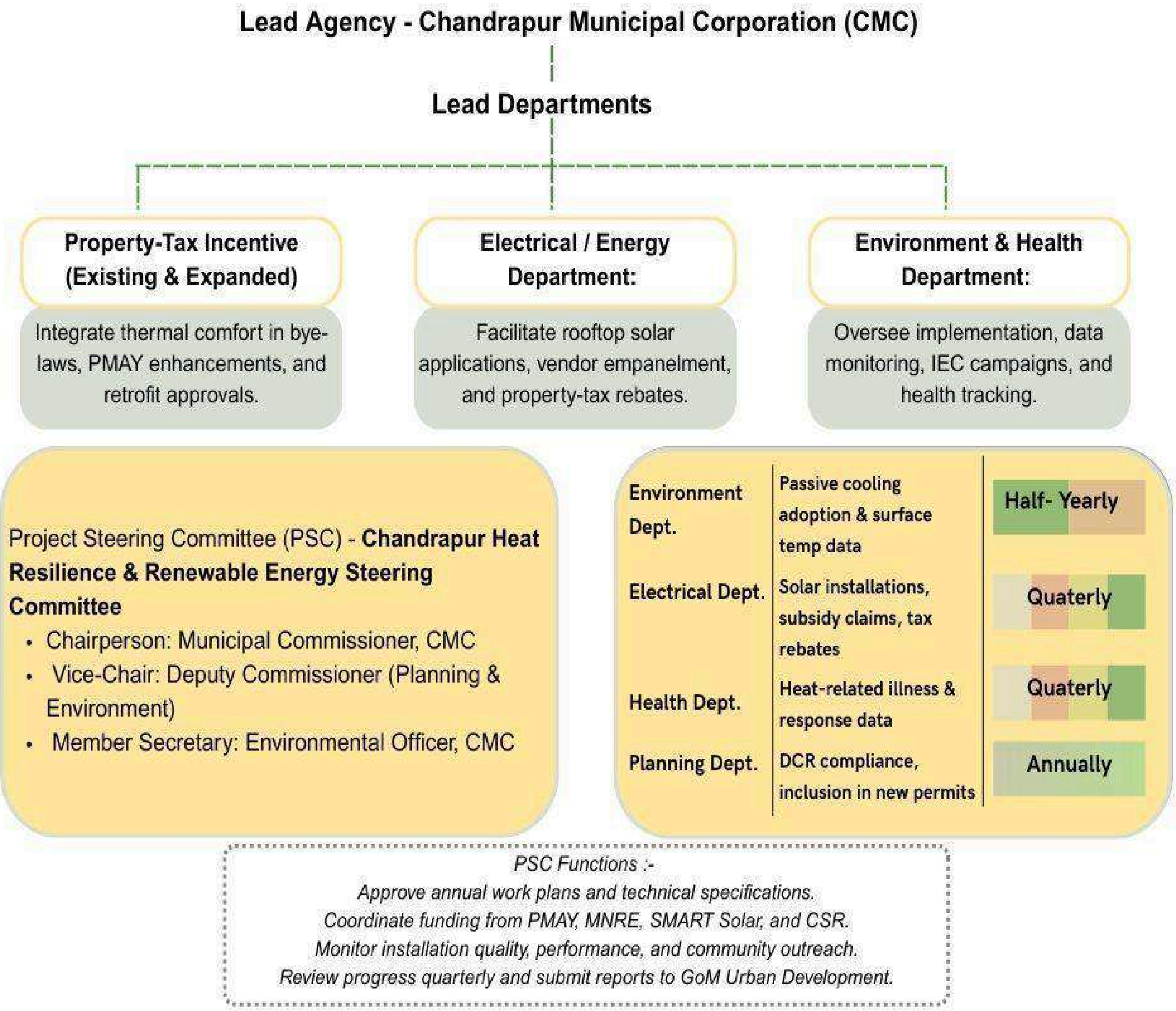


Figure 18 : Governance Framework

5. Outcomes & Early Impact

Chandrapur's unique landscape and socio-economic diversity demand climate solutions that are both locally rooted and scientifically informed. Our collaboration with the Aga Khan Agency for Habitat India, supported by global expertise from C40 Cities, marks a key step in tackling rising extreme heat and growing energy consumption. As climate change accelerates, we must pair innovative cooling solutions such as high-SRI paints, insulation sheets, and passive design measures with simple behavioural shifts like smarter energy use and improved home ventilation. AKAH's data-driven planning and community-focused initiatives further strengthen our collective resilience.

Together, we are advancing a climate-ready, inclusive, and sustainable Chandrapur that can protect and empower its people for generations to come.

- Increased understanding: People learned how simple retrofits can reduce heat by 3–5°C

- Behavior shift: Many households expressed readiness to adopt solutions like lime plaster, SRI paint, and exhaust fans
- Local champions activated: ASHA and sanitation workers became informal awareness ambassadors
- Vendors connect: Households made direct enquiries for services and products

A. Housing Mela

Held on 16 November 2025 in Chandrapur, the Housing Mela aimed to build public awareness around heat risks and simple, low-cost cooling solutions. Designed for easy access and participation, the event served as an interactive learning platform for residents, community workers, and service providers. A total of 110+ participants brought together ASHA workers, Sanitary Union members, residents from multiple wards, vendors, and dignitaries.

B. Chandrapur Municipal Corporation Policy Discussion

A stakeholder consultation was held with the Chandrapur Municipal Corporation (CMC), chaired by the Commissioner, to advance the development of Chandrapur's heat-resilience and climate-responsive housing policy framework. The session brought together line departments, scientific experts, technical partners, and key municipal officials directly responsible for implementing the Chandrapur's heat and housing strategies.

Outcomes of the Chandrapur Municipal Corporation Consultation

National and State Policy Alignment

Chandrapur's thermal comfort and renewable energy initiative operates within India's comprehensive climate policy architecture established under the National Action Plan on Climate Change (NAPCC) of 2008 and the National Mission on Sustainable Habitat (NMSH). As one of Maharashtra's first municipalities to adopt a mandatory Heat Action Plan, the city demonstrates pioneering leadership in translating national climate commitments into localized action addressing extreme urban heat vulnerability. The project adapts regulatory standards from the Energy Conservation Building Code (ECBC) of 2007 and Model Building

Bye-Laws (MBBL) for residential application in low-income settlements. While ECBC mandates minimum solar reflectance of 0.7 for commercial buildings, Chandrapur specifies Solar Reflectance Index values of 80 or higher for cool roof interventions in informal housing, representing a progressive extension of national standards. The framework incorporates provisions from the India Cooling Action Plan 2019 and Urban and Regional Development Plans Formulation and Implementation Guidelines (URDPFI), emphasizing high-reflectance roofs and passive cooling measures aligned with national cooling strategy recommendations.

Building upon the Maharashtra City Decarbonization Roadmap developed with C40 Cities and the Government of Maharashtra, the initiative positions Chandrapur as a potential model for state-level policy scaling. While Maharashtra lacks a comprehensive cool roof policy comparable to Telangana's 2023 state-wide initiative, Chandrapur's pilot program addresses gaps in existing policies that have historically emphasized commercial buildings over residential vulnerabilities in informal settlements.

Municipal Governance and Implementation Framework

The Chandrapur Municipal Corporation (CMC) demonstrates strong institutional commitment through high-level stakeholder consultations resulting in clear alignment on city-wide heat-resilience policy and housing retrofit strategy. Implementation operates through existing administrative structures utilizing ward-level facilitation desks and line departments, ensuring integration rather than parallel systems. Vendor empanelment criteria requiring Indian Standards (IS) and Ministry of New and Renewable Energy (MNRE) certifications, along with geo-tagged documentation and third-party audits, create quality assurance and accountability mechanisms within local governance.

Financial convergence with national programs including PM Surya Ghar and MNRE schemes maximizes affordability through layered subsidies combining Central Financial Assistance, Maharashtra State Electricity Distribution Company Limited (MSEDCL) support, and municipal tax rebates. Standardized Cool-Roof Kits (₹50,000-₹60,000 with IS 17218 compliance) and Solar-Lite Kits (200-300 Wp, ₹15,000-₹20,000 after subsidy) address technical and financial barriers while ensuring quality through vendor requirements of three years' experience and twenty-four-month warranties.

Addressing Barriers and Building Capacity

The framework systematically addresses critical adoption barriers identified in India's cool roof landscape. Technical barriers of limited material access are resolved through standardized kits with clear specifications. Financial constraints are mitigated through layered subsidy approaches and the Housing Mela model creating accessible entry points for subsidy registration, reducing information asymmetry and transaction costs. The pragmatic focus on cool roofs rather than green roofs reflects recognition that structural reinforcement, waterproofing, and maintenance costs make green roofs financially prohibitive for vulnerable communities. Institutional challenges are managed through clear role delineation between CMC departments, Aga Khan Agency for Habitat India (AKAH India), and C40 Cities, with phased, data-driven approaches beginning with heat-vulnerability mapping and progressive integration into city planning systems. Ward-level Heat Risk Index thresholds provide localized metrics for targeting interventions and monitoring outcomes.

Capacity building and awareness enhancement address regulatory implementation gaps through participatory Listening Workshops and Housing Melas engaging 110+ participants including Accredited

Social Health Activists (ASHA) workers, sanitary union members, and community residents. Frontline workers activated as community influencers create social infrastructure for sustained behavior change, while technical collaboration between CMC and specialized agencies enhances municipal staff capacity in heat-vulnerability assessment, thermal performance evaluation, and renewable energy integration.

Regulatory Mainstreaming and Scalability

The long-term vision involves mainstreaming passive cooling and renewable energy provisions into local building byelaws and development control regulations, shifting from voluntary to mandatory requirements for new construction in heat-vulnerable wards. Drawing lessons from Ahmedabad's Heat Action Plan integration and Delhi's low-cost design manual, the Chandrapur Cool Roof and Renewable Energy Guidelines 2025 incorporate technical specifications validated through ten representative house demonstrations, ensuring regulatory requirements ground in local performance data.

The target of retrofitting 350,000 square meters (50% of informal settlement roof area) by 2030 would reduce local heat exposure by 3-5°C, cut residential cooling energy demand by 20-25%, and save 8-10 gigawatt-hours annually. Documentation of technical performance across reinforced cement concrete, metal, and asbestos roof typologies creates replicable knowledge for other heat-vulnerable Maharashtra cities. The standardized kit approach with fixed pricing and pre-approved specifications reduces transaction costs for scaling across multiple municipalities, while the governance framework linking ward facilitation desks, vendor empanelment systems, and subsidy verification protocols provides institutional architecture adaptable to varying municipal capacities across Indian cities facing similar heat stress challenges.

- Strong alignment on the need for a city-wide heat-resilience policy and housing retrofit strategy
- Agreement on indicators for the Heat Risk Index and thresholds suited to Chandrapur's climate
- Validation of preliminary datasets, including ward-level exposure, vulnerability layers, and settlement mapping
- Clarity on roles of line departments in implementing cooling interventions and regulatory actions
- Endorsement for continued technical collaboration with AKAHI and C40 for policy drafting.

6. Conclusion

The detailed assessment of ten representative houses across Chandrapur demonstrates that context-specific passive retrofitting measures can significantly enhance thermal comfort in low-cost and informal housing typologies. Each dwelling presented distinct challenges-ranging from high heat gain through RCC and metal roofs to poor ventilation and limited shading-yet the interventions consistently proved effective in reducing indoor operative temperatures and discomfort hours.

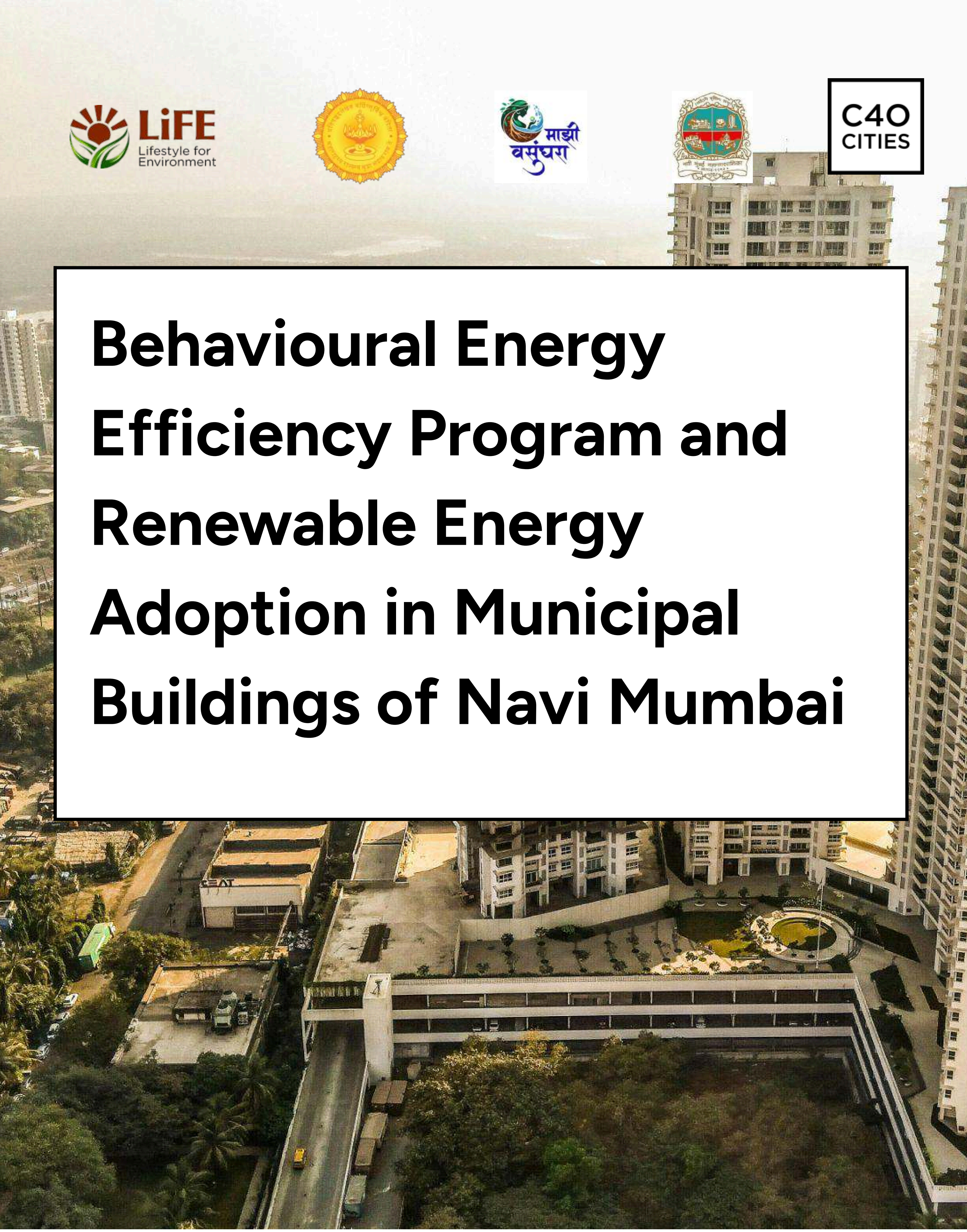
Across all typologies, roof-based retrofits yielded the most immediate impact, as roofs contributed the highest proportion of solar heat gain. Application of high SRI reflective coatings, cool tiles, and china mosaic finishes achieved average temperature reductions of 2–5°C and 30–50% improvement in comfort hours during summer months. For metal-roof dwellings, the SRI paint treatment showed the best performance due to its simplicity, low cost, and high reflectivity, reducing peak summer heat up to 4°C (≈13%).

Table : Summary of Wall and Roofs strategies

S.No.	Wall Strategies	Roof Strategies
1	SRI Paint	SRI Paint
2	no retrofit needed	Mineral wool + SRI
3	no retrofit needed	Mineral wool+ SRI
4	Lime wash+lime plaster	China mosaic tile
5	no retrofit needed	SRI Paint
6	no retrofit needed	Cool roof tile
7	SRI Paint	SRI Paint
8	Lime wash+lime plaster	SRI Paint
9	South & West wall-Lime wash+lime plaster	Cool roof tile
10	no retrofit needed	SRI Paint

Wall insulation and surface treatments-particularly lime plaster or SRI coatings-provided improved year-round stability by balancing insulation and breathability. These combinations lowered operative temperatures by 3–3.5°C, while also preventing moisture buildup and ensuring material longevity.

In cases where roof or façade exposure remained high, the integration of renewable energy-driven ventilation systems-such as solar exhaust fans and DC-powered cooling units-enhanced internal air quality and reduced humidity, particularly in compact urban plots with limited airflow. Collectively, these interventions highlight that a multi-layered passive retrofit approach-combining reflective surfaces, insulation, evaporative systems, and renewable ventilation-can achieve substantial thermal comfort gains without dependence on mechanical cooling. The strategies are adaptable, affordable, and scalable for diverse urban housing contexts, offering pathways toward energy-efficient, climate-responsive housing in warm-humid regions like Chandrapur and Vijayawada.



Behavioural Energy Efficiency Program and Renewable Energy Adoption in Municipal Buildings of Navi Mumbai

Technical Partner: SVARA SCAPE

Executive Summary

Navi Mumbai Municipal Corporation (NMMC) is taking proactive steps to decarbonise its own operations and demonstrate leadership on energy efficiency and renewable energy. This report presents the baseline energy performance of selected NMMC facilities and identifies opportunities to reduce electricity consumption through a combination of technical measures, behavioural change and rooftop solar deployment. It provides a practical roadmap for turning municipal buildings into visible examples of climate-responsive, resource-efficient public infrastructure under Majhi Vasundhara and related state and national commitments.

The assessment covers around ten representative municipal buildings, including three major hospitals (FRU Vashi, Rajmata Jijau Airoli and MCH Belapur), community halls and a major public auditorium (Gaondevi and Ahilyabai Holkar Samaj Mandirs, Vishnudas Bhave Auditorium), a sports stadium (Rajiv Gandhi Stadium, Belapur), an education facility (NMMC School No. 8 & 9), and a central medical store and disability training centre (Ghansoli Central Medical Store and ETC Disability Centre, Vashi). Together, these facilities account for a substantial share of NMMC's electricity consumption and offer strong demonstration potential across diverse building types and uses. The study combines walk-through and semi-detailed energy audits to establish baseline Energy Performance Index (EPI) values and identify major end-uses; behavioural assessments using surveys, interviews and direct observations to understand everyday practices, awareness levels and barriers to efficient use of lights, ACs and equipment; and high-level screening of opportunities for integrating rooftop solar in line with existing MERC net-metering regulations. Although the work was constrained by limited sub-metering, time-bound site visits and partial documentation in some facilities, the resulting dataset is sufficiently robust to prioritise practical, low-cost and scalable interventions.

Across the audited portfolio, electricity use remains significant relative to function and floor area, though revised calculations show that specific consumption is more moderate than initial rough estimates. Belapur Hospital, Vashi Hospital and Rajmata Jijau Hospital, Airoli each consume between roughly 0.29–0.72 million kWh per year, with EPIs in the range of about 100–120 kWh/m²·year—still substantial loads for continuously operating public health facilities, but closer to the mid-range of reported values for Indian hospitals. Vishnudas Bhave Auditorium records an EPI of around 148 kWh/m²·year, reflecting intensive, event-linked cooling and lighting, while facilities such as the Disabled Training Centre, Ghansoli Central Medical Store and Rajiv Gandhi Stadium show lower EPIs (roughly 7–75 kWh/m²·year) because of more limited conditioned areas and operating hours. For the seven buildings with complete data, annual consumption already exceeds 2.3 GWh, and the full audited portfolio of hospitals, halls, the school and other facilities together represents a substantial recurring electricity cost. Even with the revised EPI values, none of the facilities yet operate at the high-efficiency levels associated with best-practice BEE 5-star or ECBC-aligned performance, confirming the need for systematic improvements.

The energy audits reveal a consistent pattern of technical inefficiencies across building types. Air-conditioning systems rely heavily on 2–3 star split and window units and mixed ducted systems that operate for long hours, frequently in partially occupied zones and with thermostats set at about 22°C or lower. Limited zoning and controls mean that entire floors or halls are cooled even when only a few spaces are in use. Miscellaneous equipment and appliances are also sub-optimised: multiple pumps and motors run on manual control with no timers or auto shut-off; older, inefficient refrigerators and freezers operate 24/7 in cold-storage areas; and IT equipment such as PCs, printers and scanners is commonly left powered on after hours. While the overall electrical infrastructure is acceptable, circuit zoning is often poor in community halls and the auditorium, making it difficult to switch off unused areas and contributing to avoidable losses in some sites.

Indicative calculations suggest that a bundled package of technical interventions can deliver substantial savings. Full LED conversion combined with basic controls, such as occupancy sensors and better scheduling, can reduce lighting loads by about 40–50%, saving tens of thousands of kilowatt-hours annually. Upgrading HVAC systems by transitioning to BEE 5-star inverter units, improving zoning and enforcing more efficient thermostat settings can cut cooling energy use by around 20–30%, particularly in hospitals where cooling dominates the load. Replacing older fans, motors and pumps with high-efficiency IE3/IE4 models and adding timers or variable frequency drives where appropriate can further reduce auxiliary loads and improve reliability. Overall, this package of measures is expected to reduce electricity consumption in the audited buildings by roughly 25–35%, with typical simple payback periods of about 2–5 years for the major interventions.

The behavioural assessment shows that how equipment is used is as important as what equipment is installed. Across many facilities, lights and fans are left on in unoccupied rooms, corridors and halls; AC setpoints are typically kept at 22°C and seldom adjusted upwards, even during low-occupancy periods or breaks; and there are no formal standard operating procedures, circulars or building-level energy targets to guide staff behaviour. Reminder signage is almost entirely absent, and electricity bills are paid centrally by NMMC, so facility-level staff have little visibility into their consumption or costs and therefore limited direct accountability. At the same time, surveys and interviews indicate strong willingness to change practices. Staff members express interest in clear guidelines, simple tools such as posters, checklists and dashboards, and non-monetary recognition such as certificates, internal publicity and friendly competitions. Younger employees in particular are keen on "Green Office" style initiatives, suggesting a solid foundation for a structured behavioural programme.

Based on international evidence and the local behavioural baseline, behaviour-driven measures alone, such as stronger switch-off discipline, optimised AC setpoints in the 24–26°C range, better use of daylight and clearer end-of-day shutdown routines, could realistically deliver 5–10% energy savings across participating buildings at very low or no capital cost. These changes would also extend equipment life, reduce maintenance burdens and improve comfort, especially by avoiding over-cooling in hospitals and offices. Combining these behavioural improvements with targeted technical upgrades and selective rooftop solar deployment will allow NMMC to maximise the value of each rupee invested in energy management.

If the recommended package of technical, behavioural and institutional measures is implemented as proposed, the audited buildings can expect overall electricity savings of 25–35% relative to the current baseline, with 5–10% attributable purely to improved behaviour. This would translate into annual electricity savings on the order of 600–800 MWh/year across the group of facilities, corresponding to an estimated ₹1.2–₹1.6 crore/year in avoided energy costs at current tariffs. Using typical grid emission factors, the associated reduction in greenhouse gas emissions is of the order of roughly 400–650 tonnes of CO_2 per year. Beyond these quantifiable benefits, improved lighting quality and more stable indoor temperatures are likely to enhance comfort for patients, staff and visitors; modern high-efficiency equipment should reduce breakdowns and maintenance effort, particularly for critical hospital services; and visible improvements in municipal buildings will help NMMC lead by example and strengthen its performance in state and national environmental assessments.

To realise these benefits, the report proposes a phased implementation roadmap. A pilot phase over the next three to six months would implement a bundled set of technical and behavioural measures in one major hospital and one community facility, allowing NMMC to refine specifications, procurement approaches and coordination processes. A second phase over the subsequent six to eighteen months would scale proven measures across all audited buildings and other priority facilities, using bulk procurement and standardised specifications aligned with BEE 5-star and ECBC guidance. In parallel, NMMC is encouraged to adopt a Green Procurement Policy that mandates high-efficiency equipment for all new purchases, issue energy management standard operating procedures (including AC setpoint guidelines, end-of-day shutdown protocols and "last person out" responsibilities), and establish an Energy Management Cell or designated Energy Officer. A structured behavioural change programme, combining awareness sessions, bilingual communication materials, dashboards, competitions and building-level Energy Champions, will be essential to embed new practices in day-to-day operations. Over time, these steps will enable NMMC to reduce municipal operating costs, improve service quality and demonstrate a practical, replicable model for municipal energy efficiency and climate action in Navi Mumbai and beyond.

Introduction to the Study

Project Objective

The primary objective of this project is to advance the decarbonization of municipal operations in Navi Mumbai by:

1. Reducing electricity consumption in key NMMC buildings through energy efficiency and improved operational practices;
2. Designing and initiating a behavioral energy-efficiency program tailored to municipal staff; and
3. Accelerating rooftop solar adoption across a representative set of municipal facilities.

The approach integrates:

1. Building-level energy audits to identify technical inefficiencies and improvement opportunities;
2. Behavioral assessments to understand everyday practices, awareness levels, and barriers to efficient energy use;
3. Bilingual awareness and engagement tools (Marathi / Hindi / English) to ensure broad staff participation; and
4. A high-level rooftop solar roadmap, aligned with local technical, regulatory and financial conditions.

The project is designed to support NMMC's commitments under the Majhi Vasundhara Campaign, national missions on energy efficiency, and Maharashtra's renewable energy targets, while contributing to Navi Mumbai's broader climate and resilience strategy.

Project Scope

The scope of work includes:

1. Conducting walk-through and semi-detailed energy audits for approximately ten priority NMMC facilities;
2. Reviewing electricity consumption data, operating hours, and functional characteristics for each building;
3. Carrying out behavioral surveys, interviews and on-site observations with staff, facility managers and operators;
4. Developing and testing a behavioral change framework for municipal workplaces;
5. Screening rooftop solar feasibility at each site and aligning with current MERC net-metering regulations; and
6. Preparing a set of strategic recommendations and an implementation roadmap that is practical, scalable and aligned with BEE guidelines, ECBC provisions and ISO 50001 concepts (where relevant).

While this Deliverable focuses on diagnostics and planning, the intent is to generate replicable models, both technical and behavioral, that can be extended to other municipal buildings and, in the longer term, to residential and commercial consumers.

Audit Coverage

The energy audits encompassed around ten municipal facilities in Navi Mumbai, including two major hospitals, a sports stadium, a public auditorium, community halls, and office/utilitarian buildings (a medical supply center). These included Belapur Hospital, Belapur Village, Sec-11, C.B.D. Belapur, Navi Mumbai; Vashi Hospital; Rajmata Jijau Hospital, Sec-3 Airoli; Ahilyabai Holkar Samaj Mandir, Sec-9 Nerul; Gavdevi Samaj Mandir, Juipada, Sec-23, Juinagar, Navi Mumbai; Ghansoli Central Medicine Store; Rajiv Gandhi Stadium, Sec-3, C.B.D. Belapur, Navi Mumbai; School No. 8, Sector-16 Nerul; Vishnudas Bhave Auditorium, Sec-16 Vashi, Navi Mumbai; Disabled Training Center, Sec-31, Vashi. These sites represent a cross-section of NMMC's building stock and were chosen for their significant energy use or demonstration potential. Each audit involved on-site inspections, electrical measurements, and analysis of utility bills to establish the baseline energy performance.

Methodology

As part of this study, the project team carried out both technical energy audits and a user-behaviour assessment across selected NMMC buildings to understand not only how much energy is used, but also how and why it is used. The technical component focused on walk-through energy audits to document equipment, operating schedules and consumption patterns at each site, while the behavioural component used staff surveys, interviews and on-site observations to capture everyday practices, awareness levels and barriers to efficient use of lights, fans, ACs and other equipment. The subsections below describe the approach to the walk-through energy audits and subsequent data analysis; the behavioural survey methodology is outlined in a separate section.

Energy Audits Methodology

Walkthrough Energy Audits

The energy audits followed a systematic procedure in line with BEE guidelines for walk-through and detailed audits. For each building, the audit team first gathered preliminary information, including building plans, equipment inventories and past utility bills. Surveyors then conducted on-site walkthroughs to observe all energy-consuming systems: lighting (types of lamps, operating hours), HVAC (number and rating of AC units, thermostat settings), motors and pumps (rated capacities, operating schedules) and other appliances (computers, printers, refrigerators, etc.). Facility managers and key staff were interviewed to understand operational schedules and any known problem areas. Each audit culminated in a building-specific report documenting baseline conditions and recommended measures.

Figure 1: Field Visits

Rajmata Jijau Hospital Airoli

NMMC School no. 8&9, Nerul

Ahilyabai Holkar Samaj Mandir

Vishnudas Bhave Auditorium

ETC Vashi

Vashi Municipal Hospital

MCH Belapur Hospital

Medical store, Ghansoli

Rajiv Gandhi Stadium Belapur

Data Analysis

The analysis phase focused on organising and interpreting the information gathered during site visits and from utility bills. For each building, monthly and annual electricity consumption data were collated from bills and combined with floor area information to calculate the Energy Performance Index (EPI, kWh/m²·year).

These EPIs were then compared with indicative benchmarks from national studies and BEE/ECBC guidance for similar building types to understand relative performance.

End-use patterns (lighting, HVAC, pumps, plug loads, etc.) were estimated using a combination of equipment inventories, nameplate ratings, and broad area-based approximations rather than detailed sub-metering. For key systems such as ACs, lighting and fans, the team estimated the percentage of total floor area covered by that equipment (for example, proportion of wards or office space that is air-conditioned versus naturally ventilated) and combined this with typical or reported hours of use from facility staff. Simple spreadsheet summaries were then used to group loads by category and derive order-of-magnitude estimates of their relative contribution to overall electricity use. These high-level estimates helped identify which end-uses (e.g. cooling in hospitals, lighting in auditoria and community halls) were likely to be the main drivers of demand.

Potential savings from efficiency measures were estimated using published performance data for higher-efficiency technologies (e.g. LED lighting, BEE 5-star inverter ACs, high-efficiency motors) and typical savings ranges from comparable case studies, rather than from detailed equipment-level simulations. Lighting retrofits were assumed to deliver roughly 40–50% reductions in connected lighting load, while high-efficiency HVAC upgrades were assumed to reduce cooling electricity use by around 20–30% in line with published evidence. Greenhouse gas emission reductions were derived by applying a standard grid emission factor (approximately 0.82 kg CO_2/kWh) to the estimated energy savings. All key assumptions and ranges were documented to provide transparency. These analyses fed into a prioritised set of recommended measures with indicative savings, investment requirements and payback periods, intended as planning guidance rather than precise engineering designs.

Accuracy and Limitations

During the energy audits conducted across municipal offices and facilities, several practical constraints affected the depth and precision of the assessment. In many buildings, complete access to all areas and detailed operational schedules was not available, and documentation of maintenance practices was often incomplete or inconsistent. Visual inspections of lighting, HVAC units, pumps and other equipment provided useful insights, but the absence of sub-metering or real-time monitoring meant that end-use loads (e.g. separating lighting from cooling) had to be estimated using spot measurements, nameplate ratings and assumed operating hours rather than direct measurement. Because these were primarily walk-through audits, site visits were time-bound and short-term logging only captured a snapshot of operations; seasonal variations and load patterns over shifts therefore had to be inferred from monthly electricity bills and staff interviews instead of continuous monitoring. In some facilities, outdated or unlabelled electrical infrastructure complicated the creation of a fully granular load inventory, and smaller plug loads could not be measured individually within the available time. These constraints, while common in municipal settings, introduce a reasonable margin of uncertainty around baseline EPI values and end-use breakdowns, but cross-checking bills, field observations and staff inputs still provides a sufficiently robust basis to identify major inefficiencies and prioritise practical, low-cost technical and behavioural interventions.

Behavioural Assessment Methodology

Survey Design

To understand the behavioural dimensions of energy use in NMMC facilities, a concise survey and interview guide was developed for building occupants across the ten audited sites. Approximately 50 staff members from hospitals, community halls, the stadium, the training centre, the school and the medical store participated, responding to a mix of multiple-choice and open-ended questions. The survey explored awareness of energy conservation practices, individual habits (e.g. switch-off routines, thermostat preferences), perceived barriers to energy-saving actions, and suggestions for improving day-to-day operations. Questions were designed to be anonymous and non-judgmental to encourage honest feedback. In addition to the self-administered questionnaires, semi-structured interviews were conducted with facility managers and a small number of frontline staff in each building. These discussions followed a common checklist covering daily routines, roles and responsibilities, and any past initiatives or operational challenges that may have influenced energy practices. This combined instrument provided a structured but flexible framework for capturing behavioural insights alongside the technical audit.

Data Collection

The behavioural survey was administered during site visits to all ten facilities. Staff completed the questionnaire in paper form while the audit team was on site, with responses collected immediately to ensure a good completion rate. In parallel, observational data were gathered through walk-throughs to record actual practices, such as whether lights and fans were switched off in unoccupied rooms, how corridor lighting was operated, and how ACs were set and used during working hours and breaks. The team also checked for any existing circulars, notices, posters or signage related to energy saving; none were found in the audited buildings, confirming the absence of prior structured campaigns. All survey responses were compiled into a simple database and grouped by building type (e.g. hospitals, community halls, office/training spaces), while interview notes and field observations were collated as qualitative evidence to contextualise the numerical results.

Analytical Tools

The analysis of behavioural data relied on basic descriptive methods rather than complex modelling. Survey responses were summarised as simple counts and percentages to identify common patterns in awareness, habits and perceived barriers (for example, how many respondents reported routinely switching off lights, or how many were aware of recommended AC temperature ranges). Open-ended responses and interview notes were reviewed to extract recurring themes, such as discomfort concerns, workload pressures, or lack of guidance. Observational notes from the walk-throughs were used to cross-check self-reported behaviour (for instance, comparing claimed shutdown practices with the number of workstations, lights or fans actually left on after hours). Buildings were then compared qualitatively to identify where relatively better practices or stronger local leadership appeared to be present (for example, a facility where staff had informally adopted stricter switch-off routines). The objective of this analytical approach was not to produce statistically precise scores, but to synthesise multiple sources of evidence into a coherent picture of the main behavioural drivers of energy use in NMMC's municipal buildings.

Baseline Behaviour Metrics

The behavioural surveys and on-site assessments provided an indicative baseline of current energy-use practices in the audited NMMC buildings. After-hours shutdown practices emerged as a key concern: in several office and administrative areas, a noticeable share of desktop computers, fans and some lights remained on or in standby mode at the end of the workday, indicating inconsistent adherence to switch-off routines. Corridor and common-area lighting was generally operated manually, with no automated scheduling; in many cases, lights were switched on at the start of the day and left on for extended periods, regardless of actual occupancy or availability of daylight.

Thermostat settings for air-conditioned spaces were another important indicator. In many hospital and office rooms, AC setpoints were frequently observed around 22°C, which is below the 24–26°C range typically recommended for comfort cooling in warm-humid climates. This pattern points to a habit of over-cooling and the associated additional energy use.

Awareness levels were mixed. While most respondents agreed in principle that saving electricity is important, relatively few could readily identify specific, workplace-relevant actions such as optimising thermostat settings, making greater use of natural daylight, or consistently switching off appliances at the plug. At the same time, there was clear willingness to engage: many staff members, particularly younger employees, expressed interest in participating in awareness sessions, friendly energy-saving competitions or recognition programmes. Taken together, these observations establish a practical behavioural baseline against which future interventions can be designed and subsequently monitored, for example by tracking improvements in shutdown practices, thermostat settings and energy-specific awareness over time.

Reliability

As with most behavioural assessments, there are inherent limitations in data reliability. Self-reported behaviour can be subject to bias, with some respondents inclined to present their practices in a more positive light. To mitigate this, surveys were conducted anonymously and complemented with direct field observations during walk-throughs at different times of day, including unannounced visits near closing time. Where differences emerged between what was reported (e.g. "I always switch off my computer") and what was observed (equipment left on after hours), interpretation focused on the overall pattern across multiple data sources rather than on individual responses.

The sample size and period of observation are sufficient to highlight clear and recurring themes, such as over-cooling, inconsistent switch-off practices, and limited prior guidance, but are not intended to provide statistically precise, building-by-building scores. Behaviour is also likely to vary across seasons and in response to operational or staffing changes. For this reason, the current findings are treated as indicative of typical practice during the audit period, rather than as an exact year-round average.

Despite these constraints, the convergence of evidence from surveys, interviews and on-site observations provides reasonable confidence that the key behavioural issues identified are systemic and material for NMMC's municipal buildings. The baseline thus offers a robust starting point for designing the behavioural change programme, with the understanding that ongoing monitoring and periodic follow-up surveys will be needed to track progress and refine interventions over time.

Baseline Energy and Operational Data

Overview of Baseline

Baseline data was collected to establish the reference energy performance of NMMC buildings before any new interventions. This includes electricity consumption (from utility bills), operating hours, occupancy, and facility size (floor area) for each site. The baseline serves as the yardstick against which improvements from efficiency measures will be measured. In summary, the baseline assessment confirms that current energy use is quite high relative to the facilities' functions, indicating a substantial opportunity for savings through the strategies discussed.

Data Collection

Surveyors gathered utility electricity bills for each building for the past 12+ months (where available) to account for seasonal variations. For example, monthly kWh data for September 2022–August 2023 was obtained for the hospitals, stadium, and auditorium. They also compiled any available diesel generator fuel consumption (for those with backup generators, to understand total energy use, though electricity is the main focus). Gross floor area figures for each building were provided by NMMC's Estate department or measured during site visits (using laser distance meters for on-site verification in some cases and also corrected using satellite imagery). Operational schedules were documented, e.g. hospital: 24x7 for critical areas, office areas 8–10 hours daily; auditorium: event-based usage (average perhaps 4 hours/day); community halls: intermittent. Where exact data was not available (such as number of occupants at any given time), best estimates based on capacity and typical utilization were used. All baseline information was tabulated for clarity (see Appendix A for detailed tables).

Baseline Data Tables

Below is a summary table* of for the audited Navi Mumbai buildings:

Table 1: Key Baseline Metrics

Sl. No	Building	Use	EPI (kWh/m²·yr)	Performance Band*	Key Focus Area
1	**Belapur Hospital**	Hospital	**102.83**	Moderate–Low	24×7 hospital – optimise HVAC set-points, zoning
2	**Vashi Hospital**	Hospital	**121.51**	Moderate	Reduce over-cooling in OPD/admin, tighten AC schedules, solar.
3	**Rajmata Jijau Hospital, Airoli**	Hospital	**168.16**	Moderate–Low	High cooling density – inverter ACs, better zoning, monitoring.
4	**Ghansoli Central Medicine Store**	Office / Store	**73.02**	Low	Efficient base load – focus on refrigeration control, LEDs.
5	**Rajiv Gandhi Stadium, CBD Belapur**	Stadium / PSP	**6.86**	Very Low	Event-based lighting schedule, LED floodlights.
6	**Vishnudas Bhave Auditorium, Vashi**	Auditorium / PSP	**148.06**	High	Major lighting + HVAC – zoning, timers, LED stage lights.
7	**Disabled Training Centre,**	Training / Office	**74.11**	Moderate	Wiring fixes, AC scheduling, geyser timers, full LED upgrade.

	Vashi				

**(Notes: EPI = Energy Performance Index, i.e. kWh per square meter per year. Stadium floor area is taken as built/covered area, excluding the open field; its EPI is not directly comparable to fully enclosed buildings.)*

These figures show that the three hospitals dominate energy usage, together accounting for roughly two-thirds of the total consumption of the group. The hospitals also have the highest peak demands (driven by HVAC and medical equipment), whereas smaller facilities peak at lower kW levels. Energy use per square metre still varies widely: the Ghansoli Central Medical Store, for instance, has a relatively low EPI of around 29 kWh/m²·year because it functions largely as a warehouse with limited conditioned space, while Vishnudas Bhave Auditorium shows a higher EPI of about 148 kWh/m²·year due to concentrated cooling and lighting loads linked to events. This baseline table will be used to prioritise interventions (for example, focusing first on the largest consumers and on buildings with higher EPIs) and to set realistic performance targets, such as gradually reducing hospital EPIs from the current ~100–120 kWh/m²·year range toward more efficient levels over time.

[More buildings will be added in the final draft.]

Energy Use Breakdown

Where possible, energy consumption by end-use category was broken down for each building. In the hospitals, roughly 50% of electricity is attributed to HVAC (cooling) (Bhanware, Jaboyedoff, Deshpande & Shinde, 2020), about 20–25% to lighting, around 15% to medical equipment (like X-ray, sterilizers, etc.), and the remainder to other loads (pumps, fans, computers). In office or civic buildings like the auditorium or halls, lighting and HVAC together make up approximately 80% of the usage (since these are basically large conditioned spaces used for gatherings). The stadium's consumption is unique: when events occur at night, floodlighting can draw a huge load (up to 60–70% of the stadium's usage in those months), whereas on non-event days the baseline is low. For analysis, these patterns were annualized, e.g. stadium floodlights might constitute around 40% of annual energy (since they are not used daily). Having this breakdown helps in targeting measures: e.g. knowing that lighting is one-quarter of hospital energy suggests that LED retrofits can only tackle that portion, whereas HVAC optimization is critical for bigger gains.

There also existed observed temporal patterns. Buildings like offices have a pronounced drop at night and weekends (virtually zero usage then except security lights), while hospitals have a steady 24-hour profile. These usage patterns underscore the importance of scheduling interventions appropriately (for example, performing audits or installing solutions without disrupting critical operations in hospitals at peak times). One notable pattern in bills was seasonal variation, e.g. in summer months (Apr–May), energy consumption spiked to 10–15% higher (due to cooling load and maybe longer lighting hours), whereas the monsoon months saw a slight dip in AC usage.

Notable Patterns

A few patterns stand out in the revised baseline data. First, the three hospitals still exhibit the highest absolute annual energy use, but their specific consumption is now estimated in a more moderate range. Belapur Hospital, Vashi Hospital and Rajmata Jijau Hospital have EPIs of approximately 103–122 kWh/m²·year, which, while lower than initial rough estimates, still reflect intensive, round-the-clock operation and indicate clear scope for efficiency improvements in HVAC, lighting and controls. In comparison, smaller facilities such as the Disabled Training Centre (around 74 kWh/m²·year) and Rajiv Gandhi Stadium (about 7 kWh/m²·year, reflecting limited enclosed and conditioned space) show relatively lower EPIs, although targeted measures can still address specific loads like training-room ACs and event lighting. These comparisons confirm that there remains substantial potential to improve hospital energy performance against good-practice benchmarks and to optimise operations in other buildings. Due to the absence of interval metering and peak demand data, load factors and base loads could not be robustly quantified; this underlines the importance of improved metering and monitoring in the next phase to detect anomalies and track savings more precisely.

Assumptions in Baseline Data

A few assumptions were made in compiling the baseline due to data limitations. It was assumed that standard conversion factors apply (e.g. 1 unit on the electricity bill = 1 kWh) and that power factor corrections do not materially affect kWh values, as bills are primarily based on kWh/kVAh and any penalties observed were minor. For most audited buildings, 12 months of electricity bills were available; where only partial-year data existed, indicative annual figures were derived by extrapolating from the available months and clearly treated as approximate. Floor area measurements for some older buildings (e.g. community halls and training centres) were not available in updated drawings and were therefore estimated using on-site pacing, basic measurements and any legacy architectural plans, leading to an estimated uncertainty of around ±10% in area and derived EPI values. For selected load estimates (such as hospital bed-related consumption), typical occupancy levels based on design capacity (e.g. 70–80% average bed occupancy) were assumed in the absence of detailed utilisation records. Where end-use breakdowns (HVAC, lighting, plug loads) could not be directly measured, typical percentage shares from published studies for comparable Indian buildings were used and cross-checked against observed equipment inventories and any sub-meter readings shared by NMMC staff. No explicit weather normalisation was applied; the baseline reflects actual consumption in the year of analysis, with the understanding that unusually hot or mild seasons may influence cooling loads. It was also assumed that the operating patterns during the baseline period (hours of operation, service mix) are broadly representative of a normal year, with no prolonged closures or extraordinary surges in activity. These assumptions primarily affect the precision of individual metrics rather than the overall trends; they do not change the conclusion that there is substantial scope for energy efficiency improvements across the audited municipal buildings.

Detailed Findings from Audits and Assessments

Energy Audit

Baseline Data

Across the audited facilities, the equipment mix and operating profiles reveal distinct patterns by building type but a consistent story of high cooling and lighting loads with scope for optimization. In the three hospitals (FRU Vashi, Rajmata Jijau Airoli and MCH Belapur), 24×7 operations, dense distributions of split and ductable ACs, large numbers of fans, refrigeration units, sterilizers and lifts translate into very high base loads; many of these ACs are still 2–3 star units, and preventive HVAC maintenance, stricter temperature set-points (24–26°C) and better zone-wise controls are needed, alongside progressive replacement with inverter ACs, BLDC fans and clearer idle-load management. Event-centric community spaces such as Vishnudas Bhave Auditorium and the Gaondevi and Ahilyabai Holkar Samaj Mandirs are characterized by central and split AC systems, decorative lighting and large fan banks that operate intensively around functions; here, event-linked HVAC and lighting schedules, simple backstage reminders to switch off after events, occupancy-based controls and a shift away from light fixtures can substantially reduce waste. NMMC School No. 8 & 9, which relies on natural light, fans and limited IT equipment, shows that technical loads are modest and the main opportunity lies in strengthening "switch off" habits through student-led monitoring and visual prompts. The Central Medical Store in Ghansoli maintains essential cold storage with older ACs and refrigerators; ensuring tight door seals, proper temperature calibration and LED conversion in common areas can improve performance without compromising cold-chain reliability. At Rajiv Gandhi Stadium, a small number of split ACs, floodlights and fans drive highly seasonal peaks, underlining the importance of event-based lighting schedules and a gradual shift to efficient luminaires. Finally, the Disabled Training Centre (ETC) in Vashi, with 3-star ACs, fans, therapy equipment and geysers spread over multiple floors, presents a mixed profile where wiring repairs, timers on geysers, LED upgrades and basic envelope fixes (e.g. sealing cracks) can together deliver meaningful savings and improved safety.

Baseline Performance

Across the audited facilities, baseline electricity consumption remains substantial. The largest consumers are the municipal hospitals: Belapur Hospital, Vashi Hospital and Rajmata Jijau Hospital together use roughly 1.6 million kWh per year, with individual annual consumption ranging from about 0.29 to 0.72 million kWh and EPIs in the 100–120 kWh/m^2·year range. Larger non-healthcare facilities such as Vishnudas Bhave Auditorium and Rajiv Gandhi Sports Stadium fall in the tens to low hundreds of megawatt-hours annually, depending on event schedules, whereas community halls, schools, and office/store buildings have lower absolute consumption but can still record relatively elevated EPIs because of intermittent use and concentrated lighting and cooling loads (for example, halls that operate only a few hours per day but keep all lights and ACs on during setup and idle periods). For the seven facilities with complete data, the revised baseline indicates annual electricity use of over 2.3 GWh, representing a significant operating cost for NMMC even before including the remaining municipal buildings. While the recalculated EPIs are lower than earlier rough estimates, none of the facilities yet meet the high-efficiency levels expected under the Energy Conservation Building Code (ECBC) or BEE's top building rating norms, and there remains clear headroom to improve performance in a warm–humid climate context.

Identified Inefficiencies

The audits uncovered a range of inefficiencies.

Lighting

At Vishnudas Bhave Auditorium, stage lights and legacy fixtures are used extensively during events, with all circuits often left on even when parts of the hall are unoccupied. In Gaondevi Samaj Mandir and Ahilyabai Holkar Samaj Mandir, full hall lighting is frequently switched on well before and after events, despite limited occupancy, while corridors in NMMC School No. 8 & 9 and the Disabled Training Centre (ETC), Vashi were observed with lights on despite adequate daylight. This leads to both over-illumination and unnecessary operating hours.

HVAC

Air-conditioning loads are a major driver of inefficiency, particularly in hospitals and community facilities. *FRU Vashi Hospital* and *MCH Belapur Hospital* use a large number of 2–3 star split ACs and mixed ducted units, many of which operate for long hours in partially occupied wards and offices, with setpoints commonly at or below 22°C. *Rajmata Jijau Hospital, Airoli* combines central and split ACs across five floors, with limited zoning and controls, resulting in entire areas being cooled even when only a few rooms are in use. In *Gaondevi Samaj Mandir* and *Ahilyabai Holkar Samaj Mandir*, 3-star ACs are often run continuously during events without temperature optimization or staged operation. The *Vishnudas Bhave Auditorium* similarly lacks automated "event mode" controls, so ACs are manually operated and frequently left on longer than required.

Equipment & Appliances

Miscellaneous loads are also sub-optimised. In *FRU Vashi*, *Rajmata Jijau*, and *MCH Belapur Hospitals*, multiple water pumps and motors run on simple manual control, with no timers or auto shut-off, leading to extended runtimes. At the *Central Medical Store, Ghansoli*, older refrigerators and deep freezers are used for vaccine and medicine storage, operating 24/7 with limited temperature calibration and aging door seals, increasing continuous base load. Office equipment in hospitals, the *ETC Disability Centre*, and *Vishnudas Bhave Auditorium* (PCs, printers, and scanners) was frequently observed left on or in active mode after hours, adding to plug-load wastage.

Power Factor & Distribution

While overall electrical infrastructure is broadly adequate, specific sites exhibit power quality and distribution issues. At *Rajiv Gandhi Stadium, Belapur*, power factor was observed around 0.90 during peak floodlight operation, indicating reactive power losses that could be mitigated through improved compensation. In community halls and the auditorium, limited circuit zoning means large lighting and HVAC circuits remain energised even when only portions of the facility are in use (for example, backstage and lobby areas in *Vishnudas Bhave Auditorium*, or upper floors in *Gaondevi Samaj Mandir*). This lack of granular control reduces the ability of facility staff to selectively switch off unused zones, reinforcing inefficient operating patterns.

Table 2: Key Observations from Energy Audits

Category	**Building Name**	**Key Observations**	**Appliance Details (Counts / Star Ratings)**	**Efficiency & Maintenance Notes**
Hospitals	**FRU Vashi Hospital**	24×7 operations; high cooling & refrigeration loads; multiple gensets; good infrastructure but HVAC overuse.	split ACs (2–3 star), fans, PCs, printers, deep freezers, gensets, transformers.	Need strict AC scheduling & set-points (24–26°C), preventive maintenance, and idle load control.
	Rajmata Jijau Hospital, Airoli	5-floor facility; high density of ACs/fans; sterilizers and lifts add load; consistent operation.	Split + central ACs: fans ; lifts ; medical equipment: multiple autoclaves, warmers, pumps.	Replace old ACs with inverter units; introduce zone-wise HVAC controls; display usage dashboards.

	MCH Belapur Hospital	24×7 wards; mixed split and duct ACs; high fan and lab load; some outdated refrigeration.	Split/duct ACs; fans; pumps; multiple sterilizers, freezers.	HVAC system cleaning overdue; install timers for non-clinical zones; replace old fans with BLDC.
Community Halls / Auditoria	**Vishnudas Bhave Auditorium**	Large event space; high lighting & AC use; steady office loads.	Central + split ACs , stage lights, pumps, fans.	Optimize lighting schedule; automate event-mode power controls.
	Gaondevi Samaj Mandir	Seasonal/event-based usage; 12 ACs per floor (3-star); many fans and decorative lights.	split ACs (3-star), fans, LED mix.	Enforce booking-linked HVAC control; display "Switch OFF after event" reminders backstage.
	Ahilyabai Holkar Samaj Mandir	Centralized cooling; large hall capacity; all-day lighting and fan operation.	Central AC + split backup units; fans; 3-star rated.	Zonal HVAC scheduling and occupancy sensors for hall floors.
Schools	**NMMC School No. 8 & 9**	Naturally lit classrooms; no ACs; multiple lights/fans; active student use.	fans & lights; projectors in select rooms.	Strengthen "Switch Off" habits; student energy monitors; posters near classroom doors.
Offices / Stores	**Central Medical Store, Ghansoli**	Cold storage (2–8°C) maintained; older ACs; good wiring condition.	Split ACs (3-star), water coolers, exhausts, old refrigerators.	Maintain door seals; temperature calibration; LED conversion in corridors.
Stadium	**Rajiv Gandhi Stadium, Belapur**	Seasonal lighting, limited daytime office load.	split ACs, floodlights, fans, PCs/scanners.	Integrate event-based lighting schedule.
Training Centre	**Disabled Training Centre (ETC), Vashi**	4+ floors; moderate AC/fan use; summer variation; wiring	ACs (3-star), fans, therapy equipment, geysers, fridges.	Wiring repair; add timers on geysers; LED upgrade; cracks sealing.

		issues in some walls.		

Quantitative Results

The audits quantified several key parameters and associated savings potential across the audited NMMC facilities. Overall, lighting loads in buildings such as FRU Vashi Hospital, Rajmata Jijau Hospital, Vishnudas Bhave Auditorium and the community halls can be reduced by around 50% through the introduction of smarter controls (occupancy sensors in offices and training rooms, timer-based controls for outdoor and corridor lighting, and event-mode circuits in the auditorium and stadium). This alone would save tens of thousands of kWh annually across the portfolio.

HVAC-related measures present a similarly large opportunity. Phasing out old 2–3 star split/window units in the hospitals and community halls and replacing them with BEE 5-star inverter ACs, combined with better temperature control (24–26°C setpoints and zoning), is expected to deliver around 20–30% reduction in cooling energy (Bhanware, Jaboyedoff, Deshpande & Shinde, 2020). Given that cooling accounts for roughly half of total electricity use in the major hospitals, high-efficiency systems and improved controls in FRU Vashi, Rajmata Jijau and MCH Belapur Hospitals represent a particularly significant lever. Additional savings can be achieved by replacing aging fans, pumps and motors in hospitals, the Central Medical Store and the stadium with high-efficiency IE3/IE4 models and installing variable speed drives where applicable, thereby reducing pumping and ventilation loads.ì

In monetary terms, if this bundle of measures is implemented across the audited buildings, the revised baseline suggests an annual saving potential on the order of ₹1.2–1.6 crore/year, corresponding to roughly 600–800 MWh/year of reduced consumption at current tariffs. Indicative payback periods are favourable: lighting retrofits are estimated at approximately 2 years, AC replacements at 3–5 years (faster when reduced breakdowns and maintenance costs on old units are included), and pump/VFD upgrades at about 4 years, all well within the expected lifespans of the new equipment.

Potential Savings & Improvements

If the recommended efficiency measures are adopted at scale, the facilities can expect overall energy savings in the range of 25–35% relative to the current baseline. This would translate into substantial improvements in Energy Performance Index (EPI). For example, large hospitals could see EPIs fall by a similar proportion, from their current levels of roughly 100–120 kWh/m²·year to approximately 70–90 kWh/m²·year, bringing performance closer to good-practice benchmarks for public-sector facilities. Beyond hardware upgrades, simple operational improvements will be critical: enforcing an AC temperature setpoint policy (e.g. 24–25°C minimum, as recommended for warm, humid climates) can generate immediate savings, as a 1°C increase in setpoint typically reduces AC energy use by about 3–5%. Similarly, instituting clear lights-off and equipment shutdown protocols after office hours can significantly reduce wastage in offices, halls and training centres.

Importantly, many of the identified inefficiencies intersect with behavioural patterns, lights that could technically be switched off remain on, and AC setpoints remain lower than necessary due to habit or convenience. This indicates that investments in technology alone will not be sufficient; staff behaviour and supervision must improve in parallel (as further discussed in Section 3.2 on behavioural findings). Overall, the audits provide a clear roadmap of technical and operational measures, ranging from low-cost actions (such as recalibrating thermostat settings, sealing window and door gaps, and repairing leaking chilled-water lines) to capital projects (such as phased replacement of old chillers or introducing basic building automation in the stadium and major hospitals). Together, these improvements position the audited buildings to achieve considerable energy and cost savings while improving service quality.

Compliance and Standards

At present, most audited buildings do not fully align with contemporary energy performance standards. The Bureau of Energy Efficiency (BEE) star-rating framework for commercial buildings and the Energy Conservation Building Code (ECBC) were used as primary reference points. None of the facilities currently achieve energy performance levels sufficient to secure a 5-star label in their respective categories; in particular, hospital EPIs remain above values typically associated with top-performing facilities in warm-humid climates.

At the equipment level, many installed appliances do not meet best available efficiency levels, with numerous ACs, fans and refrigeration units not BEE 5-star rated. A key recommendation is therefore that NMMC adopt and enforce a Green Procurement Policy mandating that all new purchases of energy-consuming equipment (ACs, fans, pumps, refrigerators, IT hardware, etc.) meet the highest commercially available efficiency class (e.g. BEE 5-star or equivalent). Evidence suggests that 5-star appliances can be 10–15% more efficient than even 4-star models, and substantially more efficient than unrated equipment (Crompton Greaves, 2023).

Over the medium term, NMMC may also consider progressively aligning its internal energy management practices with ISO 50001 or similar frameworks, particularly for large, complex facilities such as hospitals and headquarters buildings. While such certification would be a longer-term undertaking, the immediate focus is on meeting or exceeding national standards and BEE/ECBC norms in all retrofits and new procurements, thereby locking in long-term efficiency gains.

Behavioral Assessment Findings

Assessment Process

A behavioral energy use assessment was conducted via site visits, staff interviews, and a short survey across the selected buildings. The assessment team observed daily operations (such as how and when lights/AC/fans are switched on, whether equipment is left running, etc.) and spoke with employees (administrative staff, facility managers, hospital personnel) about their routines and awareness of energy-saving measures. A questionnaire was used to gauge knowledge, attitudes, and self-reported practices regarding energy efficiency. Existing signage or reminders in the buildings related to saving electricity were also reviewed, and checked if any past campaigns or training had been done. This mixed-method approach provided both qualitative insights and some quantitative metrics.

Current Practices & Gaps

The current energy-use practices in these municipal buildings show considerable gaps from ideal behavior.

- The current energy-use practices in the audited municipal buildings display considerable deviation from good-practice norms. In terms of lighting and equipment, lights were frequently observed operating throughout the day even when daylight was adequate or areas were unoccupied. For example, in Gaondevi and Ahilyabai Holkar Samaj Mandirs, hall lighting often remained on between events, and in hospital corridors at FRU Vashi and Rajmata Jijau, full lighting was seen at midday with limited footfall. In office areas such as the Central Medical Store and ETC Disability Centre, multiple computers, printers and fans were left powered on after working hours.

- HVAC usage shows similar patterns. In several offices and outpatient areas within FRU Vashi, MCH Belapur and Rajmata Jijau Hospitals, AC setpoints were commonly maintained at around 22°C and rarely adjusted upwards, even during periods of low occupancy or during lunch breaks. In community halls, ACs were sometimes switched on well before events and left running after participants had left. Few staff reported actively moderating thermostat settings to save energy, and most were not aware that each 1°C increase in setpoint can yield measurable energy savings.
- NMMC's Engineering Department now mandates that all future air-conditioners procured for municipal buildings must carry the BEE certified 5-star rating. This directive stems from recommendations in recent energy audits, implementing a strict procurement policy to ensure only top-tier, energy-efficient AC units are installed in government facilities. The mandate, explicitly affirmed by NMMC officials during the workshop, recognizes that while 5-star air conditioners have higher upfront costs, they provide significantly lower energy consumption and reduced operating costs over their lifetime. Implementing mandatory high-efficiency equipment standards fits well within this trajectory, supporting both operational savings and compliance with national and regional energy conservation building codes.
- Awareness and accountability mechanisms are limited. While many staff members expressed a general belief that "saving electricity is good," there is no structured awareness programme, clear operating guidelines, or formal circular from management on energy-efficient behaviour. None of the audited buildings had a designated energy manager or focal point for monitoring and promoting efficient use, and reminder signage (e.g. near switches or AC controls) was virtually absent in hospitals, halls and schools. Because electricity bills are paid centrally by NMMC and not allocated to individual departments or facilities, most staff do not have visibility into consumption levels or costs and therefore feel little direct accountability for energy performance.

Table 3: Behavioral Findings & Staff Survey Insights from Municipal Buildings

Category	**Observed Behavior / Audit Findings**	**Staff Survey Insights**	**Implications for Intervention**
Lighting & Equipment Usage	• Lights left ON during full daylight in halls, offices, and hospital corridors. • Computers, printers, and fans frequently left ON overnight.	• Staff "sometimes" switch off lights/fans; often assume someone else will do it. • Curtains often kept closed, leading to unnecessary lighting use.	• Introduce visual nudges (stickers, posters). • Create simple SOPs for end-of-day shutdown. • Promote shared-responsibility routines in high-traffic areas.
HVAC Practices	• ACs are routinely set to 22°C or lower. • Rarely switched off during lunch breaks or when rooms are unoccupied.	• Several staff are unaware of energy-efficient AC setpoints. • Requested guidelines on proper AC use.	• Introduce clear AC setpoint guidelines (e.g., 24–26°C). • Add timers/occupancy sensors. • Provide quick-reference signage in rooms.

	• Low awareness that each +1°C saves energy.		
Awareness & Knowledge	• No structured energy-awareness programs. • No reminder signage in most buildings. • No designated energy manager in any facility.	• Staff cite **awareness sessions** and **posters** as major enablers. • Recognition/competitions rated higher than monetary incentives.	• Roll out bilingual training and awareness campaigns. • Place visible cues across buildings. • Introduce recognition-based programs ("Green Floor of the Month").
Accountability & Culture	• Electricity bills paid centrally → low perceived responsibility. • Staff believe energy is "someone else's concern" as long as work continues.	• Clear demand for simple instructions and shared norms. • Staff note frequent instances of ACs/lights left on in empty rooms.	• Build a culture of ownership through friendly competitions, departmental targets, and public dashboards. • Introduce micro-champions or floor energy volunteers.
Overall Pattern	• Significant gaps between ideal and actual behavior across lighting, HVAC, and equipment usage.	• Staff are willing to improve but need structure, cues, and recognition.	• Behavioral interventions are essential to align daily habits with NMMC's sustainability vision.

Key Findings

The behavioral assessment identified a mix of challenges and opportunities across the audited NMMC buildings. On the positive side, many staff members expressed willingness to adopt energy-saving habits if given clear guidance and institutional support. Younger employees in particular showed interest in "Green Office" type campaigns, recognition programmes and basic training on efficient use of lights, fans and ACs, suggesting a strong foundation for structured behaviour-based interventions.

At the same time, several behavioural barriers are evident. Awareness of the cumulative impact of everyday actions remains low: fans and ACs were often left running in unoccupied rooms in FRU Vashi, MCH Belapur and Rajmata Jijau Hospitals, and corridor lights in facilities such as ETC Disability Centre and the community halls were frequently operated on fixed routines rather than actual occupancy. Staff generally have no visibility into building-level electricity consumption or costs, resulting in limited feedback and reinforcing behavioural inertia. Cultural and hierarchical norms further influence practices; for example, in one hospital, senior clinicians' preference for very low indoor temperatures (around 18–20°C) discouraged junior staff from adjusting thermostat settings, even when over-cooling was apparent.

Despite these constraints, there are pockets of proactive engagement. At Rajiv Gandhi Stadium, a maintenance manager had already introduced a manual schedule to limit floodlight operation to match event timings, demonstrating how individual "energy champions" can influence broader practice. Similar informal initiatives were also noted in select administrative sections where staff voluntarily coordinated end-of-day switch-off routines. Overall, the assessment indicates that targeted measures, such as strengthening switch-off discipline, optimising thermostat use, and introducing simple feedback and recognition mechanisms, could realistically achieve behaviour-driven energy savings in the range of 5–10% across participating buildings. These low- or no-cost actions would complement technical upgrades and are critical to sustaining efficiency gains over time.

In Picture: NMMC Officials with representatives from C40 and SvaraScape at the Workshop conducted in November 2025

Behavioral Barriers

Several behavioural barriers to energy-conscious practices were identified across NMMC facilities. A key issue is the "split incentive": staff who operate lights, fans, ACs and equipment are not directly responsible for paying electricity bills, so there is limited individual financial motivation to save energy. Comfort and convenience also play a role. Many staff perceive turning off ACs or lights as reducing comfort or creating inconvenience, for example, waiting for rooms to cool again after switching AC back on. Informational barriers are prominent: in the absence of clear instructions, training, or building-level feedback, most employees are unaware of the aggregate impact of everyday actions such as leaving desktop computers on overnight or keeping corridor lights on continuously. Habit and routine further reinforce these patterns. Long-standing practices, like fixed schedules for switching on corridor lights regardless of occupancy, persist simply because they have "always been done that way". In some buildings, hierarchical norms discourage junior staff from adjusting AC settings or switching off lights in areas used by senior officials, even when spaces are unoccupied. The lack of formal policies, circulars or standard operating procedures on energy saving means that efficiency remains a low-priority issue in day-to-day operations. Addressing these barriers will require a combination of awareness-raising, procedural changes (e.g. assigning last-person-out responsibilities, incorporating switch-off checks into security rounds), and simple technical measures such as motion sensors and timers that reduce reliance on individual behaviour.

Impact Potential

The potential impact of overcoming these behavioural barriers is substantial. Analysis suggests that behaviour-driven changes alone, without any new equipment, could reduce electricity consumption by approximately 5–10% across the audited buildings, provided that new practices are consistently adopted and maintained. For NMMC's municipal portfolio, this translates into tens of thousands of kilowatt-hours and several lakh rupees in annual savings at virtually no capital cost, making behavioural interventions a clear "low-hanging fruit". In addition to direct energy savings, there are important co-benefits. Reduced operating hours for lights, fans, ACs and pumps will extend equipment life and lower maintenance requirements. Avoiding over-cooling can enhance thermal comfort for many staff and patients and may reduce complaints in hospitals and offices. Behavioural change in the workplace can also create positive spillovers: employees who develop energy-conscious habits at work are more likely to apply similar practices at home and in their communities. Visible commitment by NMMC staff to efficient energy use reinforces the Corporation's public image as an environmentally responsible local government and supports broader state and national climate objectives. Taken together, many small, repeated actions by hundreds of employees can result in significant and sustained reductions in municipal energy waste.

Figure 2: Campaign Material to lead Behavioural Change

Success Stories/Examples

While a structured behavioural energy-efficiency programme is new for Navi Mumbai's municipal buildings, there are internal and external examples that demonstrate the feasibility of such approaches. Internationally, several C40 cities have implemented "energy challenge" campaigns in government offices, achieving energy reductions of around 5% through awareness, feedback and friendly competition alone. In India, Mission LiFE (Lifestyle for Environment) campaigns in government institutions have shown that simple actions, such as switching off idling engines, lights and fans, can measurably reduce electricity and fuel use. Within NMMC, the case of Ghansoli School No.105 is illustrative: after rooftop solar panels were installed, the school administration became more conscious of when and how energy was used. By actively scheduling AC operation and aligning usage with solar generation, the school reportedly reduced grid electricity consumption by about 40–45% (Free Press Journal, 2023). Similarly, at the NMMC headquarters building, which has received a LEED Gold rating, facility managers maintain detailed monitoring records and systematically train maintenance staff, helping to avoid unnecessary energy wastage (Times of India, 2015). These examples indicate that when staff are given the right tools, information and institutional backing, they are able to change practices in meaningful ways. As NMMC rolls out its behavioural efficiency programme, it will be important to document building-specific success stories. For example, a hospital that reduces monthly consumption by 8% after a campaign, or a department that achieves near 100% compliance with end-of-day shutdown protocols. Sharing, celebrating and replicating these early wins will help normalise energy-conscious behaviour and encourage other facilities to follow suit.

Strategic Recommendations and Next Steps

Energy Efficiency Interventions (Facility Upgrades & Operational Improvements)

Priority Measures

Based on the audit findings across hospitals (FRU Vashi, Rajmata Jijau Airoli, MCH Belapur), community halls (Ahilyabai Holkar, Gaondevi), the Vishnudas Bhave Auditorium, the Rajiv Gandhi Stadium, the Central Medical Store and the ETC Disability Centre, a set of high-impact energy efficiency measures is recommended.

A second priority is **upgrading air-conditioning systems**. Older window and split AC units with 2–3 star ratings, observed in FRU Vashi Hospital, Rajmata Jijau Hospital, MCH Belapur, the community halls and the ETC Centre, should be progressively phased out and replaced with inverter-based BEE 5-star units or, where technically and financially feasible, more efficient centralised cooling solutions with appropriate zoning and controls. This is particularly important in 24×7 hospital spaces and frequently used large halls where usage is continuous and savings potential is significant.

The installation of **smart controls** is also recommended. These include motion or occupancy sensors for corridor and toilet lighting, event-mode and zone-wise control circuits for Vishnudas Bhave Auditorium and Rajiv Gandhi Stadium, and automatic timers or programmable thermostats for AC units in offices and multipurpose halls. Such controls can reduce unnecessary runtime during non-occupancy periods.

Another key intervention relates to **pumping and motor systems**. For water pumps, fire pumps and circulation pumps in the hospitals and stadium, timer controls should be installed to prevent unnecessary operation, and any oversized or inefficient motors should be replaced with appropriately sized, high-efficiency IE3/IE4 models. Audit observations indicated prolonged and avoidable runtimes in several buildings that can be corrected through time-clock switches and better scheduling.

To reduce **heat gain and improve cooling efficiency**, buildings should adopt measures such as solar-control window films in west-facing hospital wards and offices, interior blinds where glare is high, and proper sealing of doors and windows to prevent leakage of conditioned air. In addition, replacing old ceiling fans with BEE 5-star fans (approximately 30–35 W versus 60–75 W for conventional units) is advisable in high-density fan areas such as hospital wards, community halls, schools and the ETC Centre.

Finally, it is recommended that all future procurement of IT equipment and appliances, computers, printers, refrigerators, water coolers, etc., adhere to **energy-efficient specifications**, such as Energy Star-rated or equivalent high-efficiency models. These measures have been prioritised for their substantial energy-saving potential, direct linkage to observed inefficiencies, and practical feasibility using technologies readily available in the market.

LED Colour Temperature & Visual Comfort

For LED retrofits, energy consumption is primarily determined by wattage and efficacy, not by whether the lamp is “warm white”, “neutral/off-white” or “cool white”. For LEDs of the same power rating and product family, warm and cool variants typically use essentially the same electricity; differences in lumens per watt are marginal and should not drive selection (Energy Makeovers, 2024). For NMMC buildings in a warm–humid climate, colour temperature should therefore be chosen mainly on visual comfort and functional needs:

Hospitals and offices

Neutral “off-white” (around 3,500–4,000 K) is recommended for wards, nurses’ stations, OPDs, corridors and office areas as it provides good visual acuity without being overly harsh.

Waiting areas, patient recovery zones and residential-type spaces

Slightly warmer white (around 3,000–3,500 K) can support a calmer ambience while maintaining adequate brightness.

Task-intensive areas (labs, records rooms, admin back-offices)

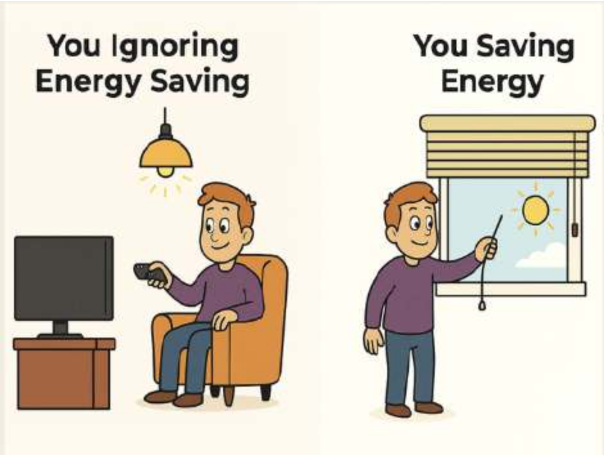
Neutral to slightly cool white (4,000–5,000 K) may be used where fine visual tasks are critical, ensuring appropriate glare control.

Standardising these ranges in NMMC’s procurement specifications will support both staff/patient comfort and consistent lighting quality across municipal facilities, while achieving the full energy benefits of LED retrofits.

Operating Practices: Switching ON/OFF Lights and ACs

A recurring question during the audits was whether frequent switching of lights and ACs increases energy use or damages equipment. For modern LED lighting, the international evidence is clear: it is almost always better to switch lights off whenever a space is not in use. LEDs draw negligible extra energy at start-up and are designed for frequent switching; turning them off even for a few minutes of non-occupancy saves net energy and does not materially shorten lamp life (Fisk, 2016). This principle should be reflected in NMMC’s operating procedures and awareness messages (“If you leave the room, switch it off”).

Global guidance suggests that even for such lamps, switching off when a room will be unoccupied for more than a few minutes is still beneficial from an energy perspective; the main consideration is maintenance planning as very rapid cycling can shorten lamp life. For air conditioners and larger motors, the practice is slightly different. Very rapid on–off cycling (for example, repeatedly switching a unit off and on within 3–5 minutes) can stress compressors and controls. However, for typical municipal use, switching ACs off for meaningful breaks (e.g. 20–30 minutes or more in offices, halls and meeting rooms) is preferable to leaving them running continuously, especially when rooms are unoccupied. In hospitals and other critical areas, thermal comfort and clinical requirements must be respected, but even there, raising setpoints to 24–26°C and switching off ACs in unused rooms or during cleaning periods are good practices. The recommended rule of thumb for NMMC is:



- **Lights (especially LEDs):** switch OFF whenever a room is unoccupied.
- **Fans and small plug loads:** switch OFF whenever not needed.
- **ACs:** avoid very rapid cycling, but switch OFF for longer unoccupied periods; otherwise use thermostat adjustment (higher setpoint) rather than running continuously at 22°C.

These practices will be embedded in the proposed Standard Operating Procedures (SOPs) and reinforced through the behavioural change programme.

Implementation Plan

The implementation of these efficiency upgrades can be staged over the next 1–2 years.

Pilot Phase (next 3–6 months)

- Select one large, high-consumption facility (e.g. FRU Vashi Hospital) and one medium/small facility (e.g. Ahilyabai Holkar Samaj Mandir or Gaondevi Samaj Mandir) for a bundled implementation of measures: LED lighting, priority AC replacements, basic controls (timers, occupancy sensors) and fan/motor upgrades where most critical.
- Use this phase to refine technical specifications, vendor selection and installation protocols, and to test coordination between NMMC's Electrical Department, facility managers and external vendors/ESCOs.

Phase 2 – Scale-up (6–18 months)

- Roll out the proven measures to all audited buildings and other priority municipal facilities in Navi Mumbai.
- Use bulk procurement (e.g. for LEDs, fans and high-efficiency ACs) to leverage economies of scale and standardise specifications.
- Plan implementation building-by-building, scheduling works during off-peak hours or weekends to avoid service disruption, especially in hospitals and the auditorium.
- Maintain structured coordination with building in-charges to sequence works floor-wise or wing-wise.

Project Management and M&V

- Establish a small core project team within NMMC (e.g. Electrical Department, Environment/Climate Cell and relevant ward offices) to oversee planning, procurement, installation and troubleshooting, with technical support from C40/SvaraScape where needed.
- Include multi-year Annual Maintenance Contracts (AMCs) for critical systems such as HVAC and central controls in procurement packages to ensure reliable performance over time.
- Set up a basic **Measurement and Verification (M&V)** process that compares pre- and post-intervention monthly electricity consumption at the building level (adjusting qualitatively for occupancy and seasonal effects), and documents realised savings and lessons learned.

Policy and Process Changes

Physical upgrades should be reinforced with supportive institutional policies and processes:

Green Procurement Policy

- NMMC may formalise (or, where relevant, update existing procurement guidelines into) a Green Procurement Policy that mandates that all new purchases of electrical equipment (ACs, refrigerators, motors, fans, lighting, IT equipment) meet the highest available energy-efficiency rating (e.g. BEE 5-star or equivalent), with standard energy-efficiency specifications included in all relevant tenders and rate contracts.

Scheduled Maintenance Protocols

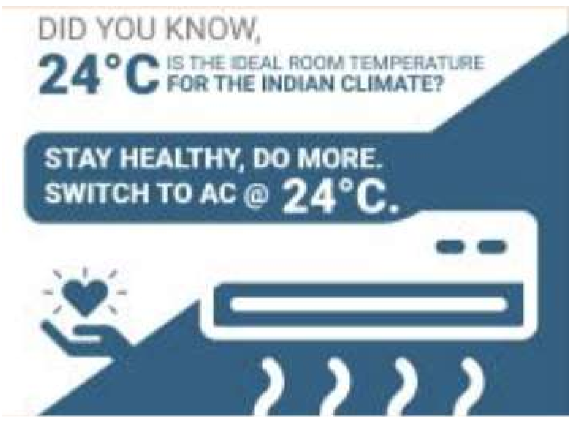
- Require pre-summer servicing of HVAC systems each year (filter cleaning, refrigerant checks, basic efficiency tuning) and annual inspection of lighting and electrical panels.

- Integrate simple energy-efficiency checks into routine maintenance (e.g. verifying thermostat settings, identifying and rectifying hot spots or loose connections).

Institutional Accountability

- Incorporate energy performance into facility managers' Key Performance Indicators (KPIs), including annual or quarterly reduction targets relative to the baseline.

- Consider establishing a dedicated Energy Management Cell or Energy Officer within NMMC to coordinate efficiency and solar initiatives, track performance and maintain institutional memory.



Energy Management SOPs

- Issue Standard Operating Procedures applicable across all municipal buildings, covering actions such as:
    - "Last person out" responsibilities for switching off lights, fans and ACs.

- Guidelines for AC thermostat settings (24–26°C) and recommended usage patterns.
- End-of-day shutdown protocols for IT equipment and non-essential loads.

Capacity Building

Human capacity is essential for sustaining technical improvements. A structured capacity-building programme is recommended:

Technical Training

- Conduct training workshops for facility managers, electricians and maintenance staff on the operation and maintenance of new systems (LED lighting, high-efficiency ACs, controls, pumps).
- Ensure vendors provide hand-holding and basic O&M manuals during and after installation.

General Staff Awareness

- Organise short, building-level sessions for administrative, clinical and support staff to explain key energy-saving practices and their relevance to service quality and municipal budgets.
- Align these with the behavioural programme described in Section 6.2 (e.g. Mission LiFE themes, “Switch Off” campaigns).

Energy Champions Network

- Nominate one or two “Energy Champions” in each building (for example, a junior engineer or supervisor) and provide them with additional orientation so they can monitor practices, support data collection and serve as local focal points.

Peer Learning

- Facilitate occasional cross-visits or virtual exchanges with other municipal corporations or institutions that have successfully implemented energy efficiency or rooftop solar programmes, to share practical lessons and build confidence.

Expected Impact

The combined impact of these facility upgrades and process improvements is expected to be significant.

Based on the current baseline of just over 2.3 GWh/year of electricity consumption for the seven audited buildings with complete data (and higher once remaining facilities are included), a comprehensive package of lighting, HVAC, fan/motor and control measures could reasonably deliver overall energy savings in the range of 25–35% once fully implemented and supported by improved operations. This corresponds to an estimated reduction of around 600–800 MWh/year across the audited facilities.

Using prevailing municipal tariffs, this saving translates to an approximate annual cost reduction of ₹1.2–1.6 crore/year, in line with the quantitative results presented earlier for the bundle of measures. At an emission factor of around 0.8 kg CO_2/kWh for grid electricity, the expected savings correspond to roughly 400–650 tonnes of CO_2 emissions avoided per year.

In addition to these quantifiable benefits:

- Improved lighting quality and more stable indoor temperatures are likely to enhance occupant comfort in hospitals, offices and public halls.
- Modern, efficient equipment with AMCs should reduce breakdowns and maintenance burdens, particularly for critical hospital HVAC and pumping systems.
- Demonstrated savings and visible upgrades in municipal facilities will help NMMC "lead by example" and can support its performance in state and national environmental assessments and campaigns.
- Over time, the combination of technical measures and strengthened institutional capacity will free up budgetary resources for other public services and increase the resilience of municipal operations to future tariff increases and grid constraints.

Overall, the proposed interventions are expected to lower energy costs, reduce the environmental footprint of NMMC's operations, and support more reliable, citizen-facing services across Navi Mumbai's municipal buildings.

Behavioral Change Program

Program Design

Education & Awareness, Engagement Tools, Incentives & Recognition

A comprehensive and on-going Behavioral Change Program was proposed to foster an energy-conscious culture in NMMC's workforce. The program will have multiple components.

Education & Awareness

This is the foundational step, conducting regular awareness workshops and training sessions for employees at all levels on simple energy-saving practices (turning off lights, efficient use of AC, etc.) and the environmental and budgetary benefits of doing so. This included development of easy-to-understand and distributed materials highlighting tips and the motto that "Energy saved is money saved for our city." In the long-run, tying into national campaigns like Mission LiFE can give context and motivation.

Figure 3: Campaign Material to lead Behavioural Change

Engagement Tools

One effective tool in the medium-run will be providing real-time feedback. For example, installing an energy dashboard in the lobby of each major building that shows current electricity consumption and how it compares to a target or past average. Seeing a display “Current usage: 50 kW, Target: 45 kW” can nudge behavior. Another tool is an internal web portal or mobile app where departments can track their monthly energy usage and savings. Commitment devices can also be used that can have staff sign a pledge or an office “green charter” to commit to certain actions.

Incentives & Recognition

To truly motivate change, a system of rewards can be incorporated. This could be as simple as an appreciation certificate from the Municipal Commissioner to the “most energy-efficient department” each quarter, or small prizes (like a team lunch or acknowledgement in newsletters) for offices that meet reduction targets. Non-monetary recognition often works well in government settings featuring success stories and names in internal communications. Another idea is to create a friendly competition or challenge (Energy Saving Challenge) between different ward offices or facilities: whoever saves the most energy percentage in a 3-month period wins a trophy or commendation. By making it fun and rewarding, people are more likely to participate actively. All these components, education, engagement, incentives, will work synergistically: awareness ensures people know *what* to do, engagement tools remind and enable them *to do it*, and incentives provide a *why* beyond just altruism.

Roll-out Plan

It was proposed that a behavior change program will be rolled out in phases.

Phase 1, Pilot (Months 1-3)

Launch the program in a few select buildings (say, NMMC HQ and one hospital). Form “Green Teams” in those buildings, small groups of volunteer employees who will champion the effort and coordinate activities. Conduct kick-off workshops where leaders communicate the importance of saving energy and announce the challenges/incentives. Put up posters and start the energy dashboards in these locations. This will also include monitoring participation and collecting feedback throughout the pilot.

Phase 2, Full Roll-out (Months 4-12)

Using lessons from the pilot, expand the program to all municipal buildings. This includes scheduling workshops in every department (could be done building by building), distributing educational materials citywide within the corporation, and setting up the monitoring dashboards in all major facilities. It will be key to synchronize this with the technical interventions schedule, as new efficient equipment is installed, that’s a great time to also reinforce behavioral measures (people will notice new lights or ACs, and that can be paired with messaging like “Now that we have efficient systems, let’s use them efficiently!”). There will then be an established routine (e.g. monthly or quarterly) of measuring each building’s energy performance and reporting it to staff, perhaps via email newsletters or a bulletin board.

Phase 3, Institutionalization (Beyond 1 year)

Integrate the behavior program into regular operations. This means making it part of the orientation for any new employee to learn about the energy policy, including energy-saving responsibilities in job descriptions for facility roles, and continuing periodic campaigns so that interest doesn't fizzle out. Possibly, an annual "Energy Conservation Week" can be institutionalized where various activities (contests, awareness drives) are held, aligning with national Energy Conservation Day on December 14th, each year.

Communication Strategy

Effective communication is critical for behavior change. This strategy will use multiple channels to reach employees. Internally, send out emails and circulars from senior officials (e.g. the Municipal Commissioner or Environment Dept.) highlighting the initiative, top-down communication signals that this is important. This also includes utilizing staff meetings: request that each department head includes a 5-minute slot in monthly meetings to discuss energy usage and encourage ideas. Visual communication in the workplace is key, hence posters, stickers (like a simple "Switch Off When Not In Use" next to light switches), and the digital displays as mentioned. Certain messages can be crafted that are positive and empowering, not scolding. For example, "Be a hero, save energy for Navi Mumbai!" rather than negative phrasing. Stories of success will be communicated: if one office achieved savings, publish that story in an internal newsletter or on the NMMC intranet site with pictures, so peers can learn and feel motivated. This can also include leveraging broader platforms: NMMC's social media handles (Facebook, Instagram, etc.) and website can share the progress of the program and even engage the public (though the program is internal, showing it publicly garners support and accountability). With that, align the messaging with broader themes like Swachh Survekshan and Majhi Vasundhara which staff are already aware of, framing energy saving as part of those environmental efforts. Language is important too, the provided materials should be available in Marathi, Hindi, as well as English to ensure all staff, including cleaning/security personnel, can understand. Regular reminders are part of the strategy: weekly tips via email or WhatsApp groups can keep energy saving on everyone's radar. Lastly, listening is part of communication, establishing a feedback channel (could be an email or dropbox for suggestions) is equally important so employees can voice their ideas or difficulties regarding the energy program, ensuring two-way communication.

Monitoring & Sustaining Behavior

To sustain the behavioral changes, continuous monitoring and reinforcement mechanisms will be put in place. This will use the energy consumption data as the primary metric, monitoring monthly bills or sub-meter readings for each building. When the reductions will be monitored, which will correlate them with actions taken, reinforcing that "X% saving happened, good job team!". If some building's consumption is creeping up, the Energy Champion or Green Team for that site will be alerted to investigate and re-engage staff there. Specific behavior metrics should be tracked: for instance, conduct periodic evening walk-throughs to count how many computers or lights are left on, and keep a log of that to see if the percentage improves over time. These metrics can be included in a quarterly report to NMMC leadership. To keep people engaged long-term, the program will continually introduce refreshers and new challenges for staff to save fuel, expanding beyond electricity. Or integrate with other aspects of Mission LiFE such as water saving, waste reduction, so the momentum carries across sustainability themes. The key is not to let the campaign stagnate; rotating messages, refreshing the posters (people tune out old posters after a while), and celebrating milestones (like "We saved ₹10 lakh this quarter!" announcements) will maintain interest. Institutionalizing the practices via policy (as mentioned earlier) will also sustain them, e.g. if an SOP says ACs off at 6 pm and this is checked by security rounds, it becomes routine rather than optional. To this end, also plan to establish a small award or recognition ceremony annually, this formal recognition by the city for internal departments (perhaps on Environment Day, June 5th) will ensure everyone knows the program is here to stay. By embedding monitoring into existing processes (like integrating energy metrics into the monthly review meetings) and keeping the program dynamic and recognized, the behavior changes are more likely to persist and even improve over time, rather than slipping back to old habits.

Figure 4: Campaign Material to lead Behavioural Change

Expected Outcomes

If this behavioral change program is successfully implemented, it is expected to have several positive outcomes. Quantitatively, as stated, a reduction of at least 5–10% in energy use attributable purely to behavior is anticipated within the first year, essentially adding to the technical savings from equipment upgrades. This translates to substantial cost savings with zero investment. Moreover, these savings are persistent and even compounding: year on year as new employees come in, they'll be indoctrinated into an energy-conscious culture, so the savings continue and potentially grow. Another outcome is an increase in awareness and capacity among the workforce, employees will become more knowledgeable about energy issues, which can also improve morale and a sense of contribution (people often feel empowered when they know they are helping save public money and protect the environment). There is an expected improved operational reliability: for instance, if staff are mindful to turn off equipment not in use, it can reduce overloads and faults, so building systems might actually run better and last longer. There's also the intangible outcome of NMMC setting a best practice example: the city government can showcase internally how it "walks the talk" on energy efficiency, which can encourage city-wide initiatives (e.g., encouraging citizens to save energy at home, since the municipality is doing it too). In terms of hard numbers, by year 2, it is expected to see each audited building's consumption trend downward noticeably on graphs, with behavior contributing a share of that. Success will also be measured by engagement levels, for example, at least 80% of staff can be anticipated to sign onto the energy pledge or participate in some event. If the program is very successful, it could even earn recognition (perhaps an award from the BEE or the state government for innovation in energy conservation at the municipal level). Overall, the outcome is a sustained reduction in energy waste, a workforce that is engaged in efficient practices, and a model program that others can emulate, firmly entrenching energy-saving behavior as the new normal in Navi Mumbai's civic offices.

Global Good Practices and Applicability to NMMC

Experiences from cities and public institutions globally show that **how people use buildings** is as important as the technology installed in them. Several behavioural design elements consistently appear in successful municipal energy programmes and are directly relevant to NMMC's proposed behavioural change initiative.

Clear goals, leadership signals and a shared story

Leading programmes start with simple, public behaviour-linked goals and visible endorsement from senior leadership. In the U.S. Department of Energy's Better Buildings Challenge, for example, participating organisations commit to portfolio-wide energy intensity reductions and regularly communicate progress internally and externally (U.S. Department of Energy, n.d.). Although the Challenge includes technical measures, a key behavioural element is that staff know there is a target, see it tracked, and understand that leadership cares.

For NMMC, a similar approach could be adopted: for instance, a corporation-wide goal such as "reduce electricity use in key municipal buildings by 20–30% over five years," combined with internal messaging that explicitly links this goal to staff actions (switch-off discipline, thermostat practices, and efficient use of equipment).

Simple behavioural rules in hospitals: "TLC-style" campaigns

Health systems internationally have shown that very simple, easy-to-remember rules can work well in complex environments like hospitals. In the UK National Health Service, the "Operation TLC" programme (Turn off equipment, Lights out, Close doors) encouraged staff to follow three core behaviours: switching off unnecessary equipment, turning off lights when areas are not in use, and keeping doors closed to maintain temperature (Barts Health NHS Trust, 2013). Evaluations found both reduced energy use and better patient comfort, demonstrating that basic, repeated actions by staff can produce measurable impact.

NMMC could adapt a "TLC-style" campaign for FRU Vashi, Rajmata Jijau and MCH Belapur Hospitals. For example, a three-point mnemonic in Marathi/Hindi/English on:

1. switching off lights/fans/ACs in unoccupied rooms,
2. using recommended AC setpoints (24–26°C), and
3. keeping windows/doors managed appropriately for comfort and efficiency.

Figure 5: Campaign Material to lead Behavioural Change

Feedback, dashboards and "social comparison"

Global experience shows that timely feedback makes energy more "visible" and encourages better habits. Many cities and public agencies use simple dashboards or "energy scorecards" in lobbies and intranet portals showing monthly consumption, progress against targets, and whether performance is improving or slipping (C40 Cities, 2020; U.S. Department of Energy, n.d.). Some programmes go further by showing comparisons between buildings or floors, tapping into friendly competition as a behavioural lever.

For NMMC, this could mean:

- a monthly energy scorecard for each major building (hospitals, auditorium, stadium, community halls),
- a simple "smiley/neutral/sad" indicator for whether the building is meeting its reduction trajectory, and
- periodic recognition of "most improved building" or "greenest floor/department" in internal communications.

Competitions, recognition and non-monetary incentives

Evidence from municipal offices and universities suggests that friendly competition and non-monetary recognition can be powerful motivators, often more effective than small financial rewards (C40 Cities, 2020). Campaigns such as "Office Energy Challenges" or "Green Office of the Month" typically combine:

- a clearly defined challenge period (e.g. three or six months),
- a simple metric (percentage reduction vs baseline), and
- visible recognition (certificates, internal publicity, small symbolic awards).

These approaches align well with public-sector cultures where honour and recognition from leadership are valued. For NMMC, quarterly challenges between ward offices, hospitals or departments, backed by acknowledgement from the Municipal Commissioner, could help normalise efficient behaviour.

Figure 6: Complete to Conserve Challenge

Local "Green Teams" and energy champions

Many successful programmes rely on embedded teams or champions inside each building rather than only a central energy unit. Cities and institutions commonly appoint "energy champions" or "green teams" who:

- remind colleagues about switch-off routines,
- help interpret dashboards,
- gather suggestions and troubleshoot practical issues, and
- act as the bridge between central guidance and day-to-day practice (C40 Cities, 2020; International Energy Agency, 2018).

For NMMC, nominating one or two Energy Champions per facility (e.g. a junior engineer, nurse supervisor, admin officer) and giving them light-touch training and recognition would support the behavioural programme described in this report. Champions can also help integrate behavioural messages with technical changes (for example, explaining how to use new AC controls correctly).

Linking behaviour with efficiency and rooftop solar

Global experience also indicates that behavioural programmes work best when linked to visible technical changes and, where relevant, rooftop solar. Many public building initiatives first reduce loads through behaviour and efficiency, then install PV sized to the lower demand, and finally use behavioural tools to maximise self-consumption (International Energy Agency, 2018). Staff can see a direct connection between their actions, the building's load profile, and the utilisation of solar generation.

For NMMC, this suggests that behavioural campaigns should be deliberately sequenced with LED/AC upgrades and rooftop solar roll-out, for example, pairing the installation of solar at Vashi Hospital with a staff campaign on "using solar wisely" (running key loads in solar hours, avoiding unnecessary night-time use, etc.). This reinforces the idea that technology and behaviour are complementary.

Application to Navi Mumbai

In practical terms, applying these behavioural lessons for NMMC would involve:

- Setting clear, time-bound energy-reduction goals and communicating them as shared staff commitments, not just technical targets.
- Launching a hospital-focused "TLC-style" behavioural campaign emphasising a few simple rules in local languages.
- Using basic dashboards and scorecards for feedback, plus friendly competition and recognition between facilities.
- Building a network of Energy Champions and Green Teams in each building to sustain engagement.
- Explicitly linking behavioural actions to outcomes such as solar utilisation, reduced bills, and improved comfort for patients and citizens.

These global behavioural good practices reinforce that the human side of energy management is central to achieving and sustaining the technical savings identified in this Deliverable, and they offer a practical template that can be adapted to Navi Mumbai's institutional and cultural context.

NMMC Solar Report

Navi Mumbai Municipal Corporation (NMMC) has already signaled a strong shift toward clean energy by planning rooftop solar installations across its buildings and civic schools, as well as pioneering a 100 MW floating solar project and mandating that all new municipal buildings under construction must have rooftop solar (Jeddy, Hindustan Times, 2023). This report presents a solar potential roadmap for a first batch of high-priority municipal buildings. It focuses on:

- Quantifying Phase-1 rooftop solar capacity (kWp) for each site.
- Estimating the share of on-site electricity demand that solar can meet.
- Providing an indicative cost estimate and emissions reduction potential.
- Outlining how these projects align with state and national rooftop solar schemes, including net metering regulations and central government programs.

The analysis and recommendations are designed for use by NMMC's engineering, planning, and finance teams as an actionable starting point for detailed design, tendering, and implementation.

Scope and Buildings Covered

This roadmap covers six representative NMMC facilities that are operationally important, have substantial and/or continuous electricity demand, and possess reasonably usable roof space:

Table 1: Buildings Covered

Sl. No	Building	Use Type
1	Belapur Hospital	Hospital
2	Vashi Hospital	Hospital
3	Rajmata Jijau Hospital, Airoli	Hospital
4	Rajiv Gandhi Stadium, CBD Belapur	Stadium / Public Use
5	Vishnudas Bhave Auditorium, Vashi	Auditorium / PSP
6	Disabled Training Centre, Vashi	Training / Office

These facilities have also been surveyed under NMMC's energy-efficiency and behavioural interventions initiative, making them ideal pilot candidates to integrate demand-side efficiency with rooftop solar.

Policy and Scheme Context

NMMC's existing and planned solar initiatives

Recent announcements and project briefs (Jeddy, Hindustan Times, 2023) highlight that NMMC is:

- Planning rooftop solar installations on new and existing municipal buildings, including ward offices and civic schools.
- Exploring a 100 MW floating solar plant on water bodies in Raigad district to supply clean power to the city.
- Linked to regional initiatives that mention 20 MW of solar PV associated with NMMC in technical project portfolios.

This roadmap directly supports those commitments by providing a detailed, building-level implementation plan for a first tranche of rooftop systems.

National rooftop solar programme (MNRE – Phase II)

The Ministry of New and Renewable Energy, Government of India outlines the Grid Connected Rooftop Solar programme, which targets 40,000 MW of installed rooftop capacity through central financial assistance to residential consumers and incentives to DISCOMs.It provides:

- Central Financial Assistance (CFA) / subsidy to residential consumers, and
- Incentives to DISCOMs for achieving rooftop targets

While municipal buildings are not the primary beneficiaries of direct CFA under current guidelines, NMMC can still leverage:

- DISCOM-level incentives (e.g., through MSEDCL) to prioritize municipal projects;
- Capital subsidies and concessional financing available for institutional buildings such as schools, hospitals, and public-sector facilities, as described in sectoral guidance and financing summaries.

These mechanisms can significantly reduce upfront costs for NMMC's rooftop programme, especially in aggregation across multiple buildings.

Maharashtra's net metering and group / virtual net metering

Rooftop solar in Navi Mumbai operates under the Maharashtra Electricity Regulatory Commission (MERC) regulations:

- MERC (Net Metering for Rooftop Solar PV Systems) Regulations, 2015 provide the basic framework for net metering in the state.
- Recent MERC orders (2024–2025) have reaffirmed the right to net metering even where utilities attempted to shift projects to gross metering, and have clarified that consumers can simultaneously use net metering for rooftop solar and open access for other power needs.
- MERC has also enabled virtual / group net metering in Maharashtra, allowing group housing societies to share a common rooftop plant and allocate credits virtually across individual meters.

For NMMC, these regulations mean that:

- Each municipal building can adopt standard net metering up to the applicable capacity limits.
- Over time, NMMC could also explore group net metering for clusters of facilities (for example, using a large rooftop at one site to serve nearby low-roof sites).

Overall, this policy environment is favourable to a scaled municipal rooftop programme, provided that project design and approvals are handled systematically.

Methodology

This section describes how the Phase-1 rooftop solar capacities and demand coverage percentages were derived for the six buildings.

Data collection and EPI assessment

For each building, the following data were collected:

- Monthly electricity bills (at least 12 months) to determine annual kWh consumption.
- Built-up floor area (m²) from municipal drawings and site verification.
- Operational profile – days and hours of operation, typical occupancy, and seasonal patterns (e.g., hospitals as 24×7 loads; stadium and auditorium as event-based loads).

The resulting EPIs and a qualitative performance band were:

Table 2: Building-wise EPI and Performance Bands

Sl. No	Building	Use	EPI (kWh/m²·yr)	Performance Band*	Key Focus Area
1	Belapur Hospital	Hospital	102.83	Moderate–Low	24×7 hospital – optimise HVAC set-points and zoning
2	Vashi Hospital	Hospital	121.51	Moderate	Reduce over-cooling in OPD/admin, tighten AC schedules, add PV
3	Rajmata Jijau Hospital, Airoli	Hospital	168.16	Moderate–Low	High cooling density – inverter ACs, better zoning, monitoring
4	Ghansoli Central Medicine Store	Office / Store	73.02	Moderate	Efficient base load – focus on refrigeration control, LEDs
5	Rajiv Gandhi Stadium, CBD Belapur	Stadium / PSP	6.86	Very Low	Event-based lighting schedule and full LED floodlights
6	Vishnudas Bhave Auditorium, Vashi	Auditorium / PSP	148.06	High	Major lighting + HVAC – zoning, timers, LED stage lighting
7	Disabled Training Centre, Vashi	Training / Office	74.11	Moderate	Wiring fixes, AC scheduling, geyser timers, full LED retrofit

**Performance band is indicative, based on typical benchmarks for Indian institutional buildings and field judgement.*

Buildings with moderate to higher EPI (e.g., Vishnudas Bhave Auditorium at ~148 kWh/m²·yr and Rajmata Jijau Hospital at ~168 kWh/m²·yr) were flagged as priority candidates for aggressive efficiency measures before/alongside solar: LED retrofits, better HVAC control, timers, and zoning. Lower-EPI sites were treated as already relatively efficient but still suitable for rooftop solar.

Roof assessment and technical potential

For each site, roof potential was evaluated through:

- Satellite imagery and layout plans to map gross roof area.
- On-site visits to identify:
  - Permanent shading (water tanks, lift rooms, nearby buildings, trees).
  - Structural constraints (set-backs, parapets, existing equipment).
  - Access routes for installation and maintenance.
- Usable roof area was then estimated by excluding:
  - Heavily shaded or inaccessible portions.
  - Set-backs needed for safety and maintenance.
  - Non-negotiable equipment footprints.
- Existing solar systems: During roof assessment, we recorded existing solar assets (e.g., solar geysers at Rajmata Jijau Hospital and existing PV arrays at Belapur Hospital). For these buildings, Phase-1 rooftop PV sizing is incremental, taking into account:
  - available free roof area after existing systems,
  - shading from geyser structures and adjacent parapets, and
  - the need to avoid major relocation costs unless payback is justified.

We assumed only 60–70% of the gross roof area was actually usable for PV modules, consistent with typical Indian public-sector rooftop projects.

Solar resource and system performance assumptions

To size rooftop PV, the following key assumptions were used, based on Navi Mumbai's climate and India-wide norms:

- Solar irradiation: Approx. 5.0 kWh/m²/day of global horizontal irradiation (GHI), typical for the Navi Mumbai region.
- System yield: Around 1,600–1,700 kWh per kWp per year, based on comparable rooftop projects in western India.
- Performance ratio (PR): 80% (accounts for inverter losses, wiring, soiling, temperature, and other system losses).
- Tilt and orientation: Panels tilted at ~10–15° and oriented roughly south, which is feasible on flat RCC roofs.
- Degradation: 0.5–0.7% per year in energy output, reflecting standard mono-PERC module performance.

Using these assumptions, a simplified annual yield of 1,650 kWh/kWp/year was adopted for modelling.

Sizing logic and demand coverage

The sizing objective for Phase-1 was not simply "maximum kWp on the roof", but a balanced system size that:

- Maximizes on-site consumption (self-use) to avoid significant daytime export.
- Targets 20–70% of annual electricity demand depending on the building type and space available.
- Keeps future expansion options open through modular additions (Phase-2, Phase-3).

Using each building's annual consumption and the assumed yield (1,650 kWh/kWp/year), we iteratively tested system sizes to meet target coverage levels. The agreed Phase-1 capacities and indicative coverage are:

Table 3: Solar Potential (kWp) and Annual Demand Met

Building	Recommended kWp (Phase-1)	Approx. % of Annual Demand Met
Belapur Hospital	93.4	23%
Vashi Hospital	294.5	58%
Rajmata Jijau Hospital, Airoli	136.2	66%
Rajiv Gandhi Stadium, Belapur	6.3	70%
Vishnudas Bhave Auditorium, Vashi	97.0	24%
Disabled Training Centre, Vashi	36.6	70%

These percentages reflect the match between annual PV generation and recent annual electricity consumption from utility bills.

Cost estimation

To estimate indicative capital expenditure (CAPEX), we used benchmark rooftop solar prices observed across Indian cities. Public-sector institutional projects in 2024–2025 typically fall in the range of ₹45,000–70,000 per kWp, depending on plant size, module type, and tender competitiveness. For planning purposes we adopt a mid-range ₹60,000/kWp, inclusive of:

- Solar modules, inverters, structure, cabling, and protection.
- Design and engineering.
- Installation and commissioning.
- Basic monitoring systems.

Annual operations and maintenance (O&M) costs are expected to be 1–2% of CAPEX, covering cleaning, routine inspection, inverter spares, and minor repairs.

Building-wise Solar Potential Analysis

Using the assumptions above, annual PV generation for each building is:

Table 4: Solar Potential Analysis Summary

Building	Use Type	EPI ($kWh/m^2 \cdot yr$)	Phase-1 Size (kWp)	Est. Generation (kWh/yr)	Demand Met (%)	Indicative CAPEX (₹ lakh)
Belapur Hospital	24×7 Hospital	102.83	93.4	154,110	23%	~56
Vashi Hospital	24×7 Hospital	121.51	294.5	485,925	58%	~177
Rajmata Jijau Hospital, Airoli	24×7 Hospital	168.16	136.2	224,730	66%	~82
Rajiv Gandhi Stadium, Belapur	Stadium / PSP	6.86	6.3	10,395	70%	~4
Vishnudas Bhave Auditorium, Vashi	Auditorium / PSP	148.06	97.0	160,050	24%	~58
Disabled Training Centre, Vashi	Training / Office	74.11	36.6	60,390	70%	~22
Total	—	—	≈664 kWp	≈1,095,600	—	~399 lakh (₹3.99 cr)

Note: CAPEX estimates are indicative and based on a planning assumption of ₹60,000/kWp; tendered prices may be lower with aggregation.

Environmental benefits

Using the Indian grid emission factor ~0.82 kg CO_2/kWh (as recommended by recent carbon accounting guidance referencing CEA data), the combined 1.0956 GWh/year of solar generation would avoid approximately:

1,095,600 kWh/year×0.82 kg CO_2/kWh≈898,000 kg CO_2/year1{,}095{,}600\ \text{kWh/year} \times 0.82\ \text{kg CO_2/kWh} \approx 898{,}000\ \text{kg CO_2/year}1,095,600 kWh/year×0.82 kg CO_2/kWh≈898,000 kg CO_2/year

That is, about 900 tCO_2e per year avoided across these six buildings alone. Over a 25-year lifetime (ignoring minor degradation for simplicity), this corresponds to ~22,500 tCO_2e of cumulative emissions reductions.

Building-wise narrative

a) Belapur Hospital – 93.4 kWp (23% demand)

Belapur Hospital has a moderate-low EPI (~103 kWh/m²·yr), reflecting reasonably efficient base operations but substantial 24×7 loads (lighting, medical equipment, cooling). A 93.4 kWp system sized to available, unshaded roof area would generate ~154 MWh/year, supplying roughly one-quarter of total electricity use. The system is sized conservatively to ensure most generation is self-consumed during daytime, minimizing expBelapur Hospital already has a small rooftop solar PV installation in operation; the recommended 93.4 kWp should therefore be treated as additional capacity, subject to confirming available shadow-free area and electrical integration with the existing plant.ort and simplifying net-metering.

b) Vashi Hospital – 294.5 kWp (58% demand)

Vashi Hospital exhibits a higher EPI (~122 kWh/m²·yr), driven by intensive cooling and long operating hours. Before solar installation, it is recommended to tighten AC schedules, especially in outpatient and administrative areas, and reduce over-cooling. Even with such measures, the building's load remains high, allowing a larger PV plant (294.5 kWp) without excessive surplus. Estimated generation (~486 MWh/year) can meet around 58% of the hospital's annual demand. This makes Vashi Hospital the anchor project of Phase-1, both in capacity and in visibility.

c) Rajmata Jijau Hospital, Airoli – 136.2 kWp (66% demand)

Rajmata Jijau Hospital is a medium-sized 24×7 facility with a moderate-low EPI (~168 kWh/m²·yr) and relatively favourable roof geometry. The recommended 136.2 kWp system is designed to push toward a two-thirds renewable supply on an annual basis, yielding ~225 MWh/year. Given the high share of cooling loads, pairing this with inverter-based ACs, zoning, and improved controls will further improve self-consumption by matching generation with daytime cooling.

The roof currently hosts a solar water-heating (geyser) system, and portions of the array experience partial shading. The PV layout will need to work around this infrastructure (or selectively relocate collectors) and account for shading in the generation estimates, potentially reducing net yield slightly relative to an unshaded roof.

d) Rajiv Gandhi Stadium, CBD Belapur – 6.3 kWp (70% demand)

This stadium has very low EPI (~6.9 kWh/m²·yr) because it is illuminated and occupied mainly during events. A smaller 6.3 kWp plant can nonetheless cover about 70% of its annual electricity when combined with LED floodlights and smart scheduling. Here, the rooftop plant serves more as a demonstration project and a testbed for integrating solar into public-use, event-driven facilities.

e) Vishnudas Bhave Auditorium, Vashi – 97.0 kWp (24% demand)

The auditorium's EPI (~148 kWh/m²·yr) is high due to concentrated lighting and HVAC loads during performances, rehearsals, and functions. A two-step strategy is recommended:

- Aggressive efficiency measures (full LED upgrade, zoning, occupancy-based controls, and HVAC timers).
- A 97.0 kWp plant that generates ~160 MWh/year, covering around 24% of annual electricity use.

Once efficiency gains are validated, the plant can be augmented in a Phase-2 expansion, subject to roof capacity.

f) Disabled Training Centre, Vashi – 36.6 kWp (70% demand)

This training and office facility has a moderate EPI (~74 kWh/m²·yr) and relatively modest base load. Wiring and safety fixes, LED retrofits, and AC/geyser scheduling should be implemented alongside a 36.6 kWp plant. The expected generation (~60 MWh/year) can meet around 70% of the building's demand, making it a high-impact yet relatively low-cost pilot for educational and social-sector facilities.

Financial and Co-Benefit Analysis

Capital costs

Using the ₹60,000/kWp benchmark, total Phase-1 CAPEX is estimated at ₹3.9–4.0 crore. With competitive bidding and potential use of standard rate contracts, actual costs may fall toward the ₹50,000–55,000/kWp range, particularly for a bundled tender above 500 kWp.

Electricity bill savings

Assuming an average effective tariff of ₹8.0–9.0/kWh for these institutional consumers (including energy charges, demand charges, and taxes), the annual generation of ~1.1 GWh would yield:

- ₹8.8–9.9 million per year (₹0.88–0.99 crore) in avoided electricity purchases.

This is broadly in line with savings observed in other Indian cities where multiple civic buildings have adopted rooftop solar; for example, one municipal corporation reported ₹5.9 crore in savings over two years from rooftop plants on 80+ civic buildings.

At this savings level, the simple payback period for NMMC would likely be in the 7–9 year range, before considering additional benefits such as avoiding future tariff hikes, reputational gains, or carbon finance.

Alignment with green building and net-zero ambitions

NMMC is already part of a broader "greener Navi Mumbai" agenda, with IGBC and local architects promoting net-zero building designs for municipal infrastructure.

4. Installing rooftop solar on hospitals, training centres, and cultural venues directly supports net-zero energy building pathways.
5. The combination of energy efficiency + rooftop solar is a key stepping stone toward NMMC's broader net-zero and climate-resilient city vision, alongside the proposed 100 MW floating plant.

Implementation Roadmap

To convert this roadmap into operational projects, we propose the following phases:

Phase 1 – Preparation (0–6 months)

- Institutional set-up
  - Form a small "Municipal Solar Cell" with representatives from electrical, planning, accounts, and legal departments.
  - Designate building-level nodal officers for each of the six sites.
- Detailed technical and structural assessment
  - Conduct structural checks (load-bearing capacity, wind load, waterproofing) and finalize usable roof areas.
  - Confirm wiring route, inverter placement, and net-metering point for each site.
- Refined techno-economic analysis
  - Update CAPEX/OPEX estimates with current market quotations.
  - Confirm tariff structure and expected bill savings using recent MSEDCL bills.
- Scheme and financing alignment
  - Engage with DISCOM and MNRE nodal agencies to explore:
    - Any institutional capital subsidies or special lines of credit for municipal buildings.
    - Possible integration with MERC-compliant net metering and, in future, group/virtual net metering for clusters.
- Stakeholder consultation
  - Workshops with hospital administrators, stadium and auditorium managers, and training centre staff to explain the project, agree on access, and align expectations on operations and maintenance.

Phase 2 – Procurement and Installation (6–18 months)

- Tendering and vendor selection
  - Issue a bundled EPC tender covering all six buildings with a single BoQ and unified performance specifications.
  - Evaluate vendors based on technical compliance, price, experience with institutional projects, and O&M commitments.
- Implementation
  - Execute installations in logical clusters (e.g., hospitals together, then public spaces).
  - Implement efficiency measures (LEDs, HVAC controls) in parallel to maximize self-consumption from day one.

- Net-metering approvals
    - Coordinate closely with MSEDCL for meter replacement, net-metering agreements, and portal approvals, ensuring compliance with MERC regulations and recent clarifications on capacity limits.

Phase 3 – Monitoring, Optimization, and Scale-up (18–36 months)

- Performance monitoring
    - Install online monitoring systems for each plant (or a centralized dashboard) to track generation, PR, and savings in real time.
    - Use data to identify underperforming strings, inverter downtime, and soiling losses.
- Behavioural and operational integration
    - Tie solar generation data into behavioural campaigns for staff (e.g., "Our hospital is now 60% solar during the day – help us reach 70% by switching off unused loads").
    - Adjust AC and lighting schedules to better match solar generation profiles.
- Scale-up to additional buildings
    - Based on lessons learned, prepare Phase-2 for:
        - Remaining NMMC hospitals and health facilities.
        - Ward offices, schools, administrative buildings, and public toilets already identified by NMMC for solar deployment.

Risk Assessment and Mitigation

Risk Category	Description	Suggested Mitigation
Regulatory / approvals	Delays or uncertainty in net-metering approvals, portal issues	Early engagement with MSEDCL; align with latest MERC orders; use standard application formats
Technical / structural	Roof not structurally adequate, water leakage, shading issues	Detailed structural vetting; pilot load tests; waterproofing and proper drainage design
Operational	Poor O&M leading to reduced performance	AMC contracts with clear KPIs; staff training; monitoring dashboard
Financial	Tariff changes or lower-than-expected savings	Conservative assumptions; sensitivity analysis; locking in long-term PPAs where feasible
Social / institutional	Limited buy-in from building managers or staff	Early consultations; visible displays of solar performance; link to CSR and public recognition

MERC's recent interventions in enforcing net-metering rights for other public entities demonstrate that regulatory clarity is improving, but NMMC should still track state-level orders closely.

Role of NMMC's Rooftop Solar Schemes and Future Opportunities

NMMC's decision to mandate solar on all new buildings and to prioritize ward offices and civic schools for rooftop installations is, effectively, the beginning of a municipal rooftop solar scheme. To formalize and strengthen this:

9. NMMC could publish a "Municipal Rooftop Solar Policy" that:
    a. Sets staged targets (e.g., 5 MW on municipal roofs by 2027, 20 MW by 2030).
    b. Defines standards for system design, metering, and monitoring.
    c. Gives clear priority to critical facilities (hospitals, disaster-response centres).
10. NMMC can also develop a showcase net-zero building (for example, a new ward office or training centre), in line with IGBC's discussions on net-zero municipal buildings in Navi Mumbai.

These steps, combined with the 100 MW floating solar plant, can position Navi Mumbai as a state leader in municipal renewables, similar to how other Indian cities have demonstrated large savings and strong visibility from solarizing dozens of civic buildings.

Way Forward

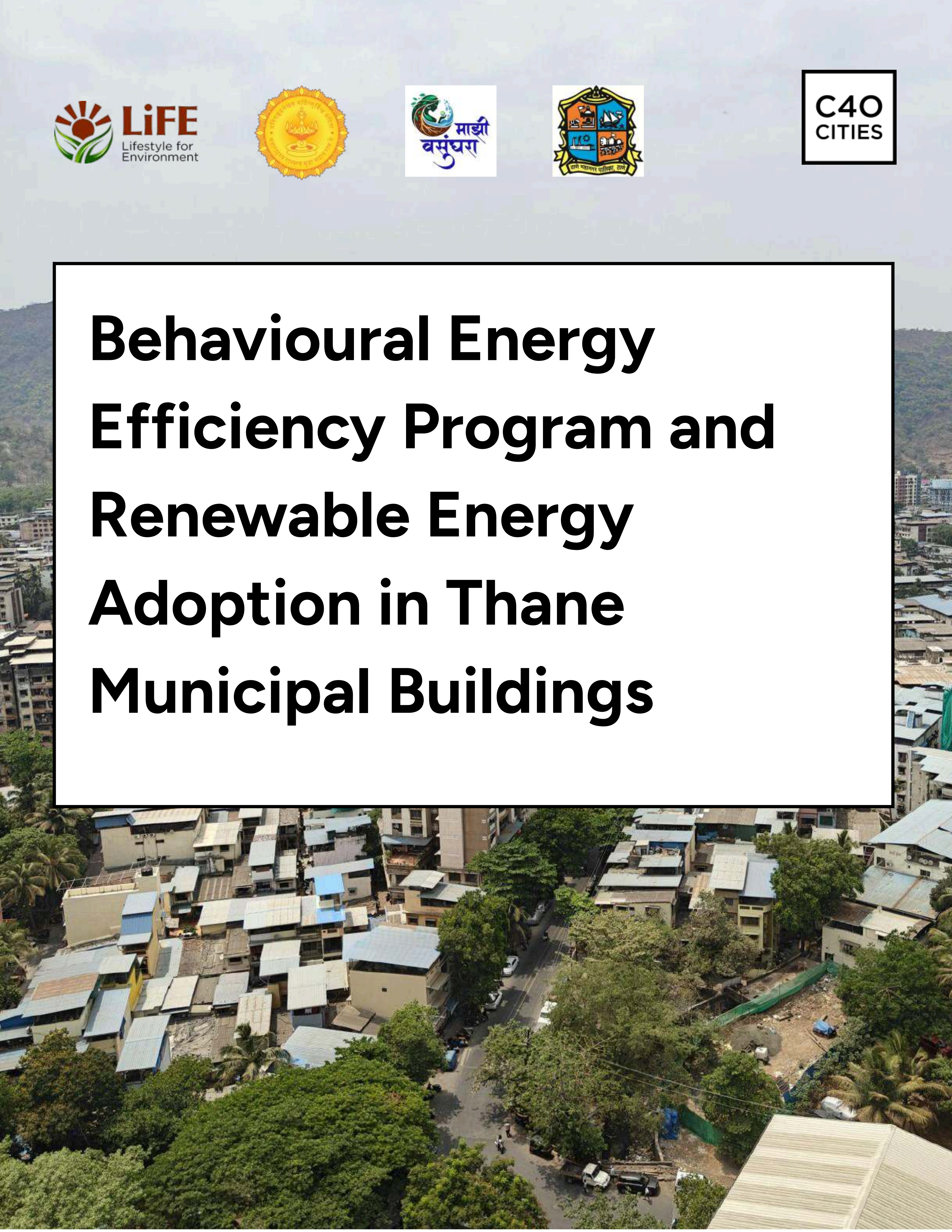
This solar potential roadmap demonstrates that:

- A modest set of six priority municipal buildings can already host ~664 kWp of rooftop solar.
- These systems can collectively supply ~1.1 GWh of clean electricity per year, offsetting nearly 900 tCO_2e annually at current grid emission factors.
- With indicative CAPEX of ₹3.9–4.0 crore and annual bill savings approaching ₹1 crore, the financial case is strong, especially when combined with available incentives and NMMC's broader net-zero infrastructure agenda.

By rolling out Phase-1 as described, NMMC can:

- Reduce operating costs for hospitals, public spaces, and social facilities.
- Build internal capacity and confidence to scale rooftop solar across its entire building stock.
- Tangibly demonstrate progress toward a cleaner, climate-resilient Navi Mumbai, reinforcing its leadership among Indian urban local bodies.

Behavioural Energy Efficiency Program and Renewable Energy Adoption in Thane Municipal Buildings



Technical Partner: SVARA SCAPE

Executive Summary

Thane Municipal Corporation (TMC) is taking important steps to strengthen the energy performance of its own operations and demonstrate leadership on climate-responsive governance, energy efficiency and renewable energy adoption. This report presents the baseline energy performance of nine representative TMC facilities and identifies opportunities to reduce electricity consumption through a combination of targeted technical upgrades, behavioural change measures and expanded rooftop solar deployment. Together, these elements provide a practical roadmap for transforming Thane's municipal buildings into visible examples of resource-efficient, climate-aligned public infrastructure consistent with the goals of Majhi Vasundhara, the State Climate Action Framework and national energy efficiency commitments.

The assessment covers a diverse range of municipal buildings that reflect Thane's heterogeneous service delivery landscape. These include the city's main administrative headquarters at Pachpakhadi, the Vartaknagar Ward Office (which also houses the municipal environmental laboratory), two municipal schools (School No. 53 and School No. 55), Swa. Meenatai Thakare Maternity Home, the Wagle Bus Depot administrative and workshop complex, the Dadoji Kondev Stadium building, the eight-floor Cluster Cell office complex, and a BSUP residential building in Tulshidham. Collectively, these facilities span office administration, healthcare, education, sports infrastructure, laboratory operations and residential services, forming a substantial share of TMC's total municipal building electricity use and offering strong demonstration potential across multiple building typologies.

The study combines walk-through and semi-detailed energy audits to establish baseline Energy Performance Index (EPI) values, equipment inventories and major end-use loads; behavioural assessments through structured surveys and interviews to understand operational routines, awareness levels and barriers to efficient use of lights, air conditioners and equipment; and preliminary screening of rooftop solar feasibility in line with applicable MERC net-metering regulations. Although the assessment faced challenges, including incomplete billing data for some facilities, time-bound site visits, partial documentation of equipment, and the exclusion of the Chhatrapati Shivaji Maharaj Hospital due to limited departmental cooperation, the overall dataset is sufficiently robust to identify high-impact opportunities and cost-effective interventions.

Across the audited portfolio, electricity consumption is substantial relative to the size and function of the buildings, with significant variability in EPI values. The TMC Main Office consumes approximately 1.2 million kWh per year, driven by heavy administrative loads, widespread use of 2–3 star AC units, high densities of computers and printers, and limited control over cooling operations. The Cluster Cell office consumes approximately 209,000 kWh per year, while the Vartaknagar Ward Office consumes around 102,000 kWh annually, reduced to roughly 61,000 kWh due to the performance of its 25 kW rooftop solar plant, which offsets around 43 percent of its annual consumption. Updated EPI values show that most administrative facilities now sit in the moderate-to-low performance band, with the TMC Headquarters at 66.85 kWh/m²·year (moderate–low), Vartaknagar Ward Office at 37.81 kWh/m²·year (low), Cluster Cell at 27.12 kWh/m²·year (low), and Wagle Bus Depot at 28.85 kWh/m²·year (low). The Tulshidham BSUP building's common areas have an EPI of approximately 3.8 kWh/m²·year, reflecting very low consumption in shared spaces. Nonetheless, none of the surveyed buildings currently meet the performance levels associated with BEE 5-star ratings or ECBC-aligned operations for similar climate zones, indicating substantial remaining potential for improvement.

The energy audits reveal recurring patterns of technical inefficiency across sites. Air-conditioning systems rely heavily on older 2–3 star split and window units, many installed before 2015, leading to elevated cooling loads. AC setpoints are generally maintained at 22–24°C, below recommended BEE guidelines, and ACs often operate alongside ceiling fans, resulting in unnecessary cooling penalties. Water pumps across multi-storey buildings (such as Tulshidham BSUP) operate manually for extended durations without timers or automatic shut-off controls, creating significant pumping inefficiencies. In specialized facilities such as the Vartaknagar environmental laboratory, older hot air ovens, COD digestors and spectrometers contribute additional loads during working hours. Multiple administrative buildings report PCs, printers and auxiliary office equipment powered on after hours, contributing a persistent 3–10 percent idle load. At Wagle Bus Depot, poor envelope conditions, including broken windows, inadequate insulation and exposed wiring, create both safety concerns and thermal losses that exacerbate cooling loads.

Indicative calculations suggest that a bundled package of technical interventions can deliver substantial savings. Replacing all remaining lighting with LEDs, paired with occupancy sensors and better daylight integration, can reduce lighting energy use by 40–50 percent. Upgrading all AC units to BEE 5-star inverter models and introducing zoning and automated controls can reduce cooling loads by 20–30 percent, particularly in large administrative buildings. Retrofitting pumps, motors and exhaust systems with high-efficiency IE3/IE4 models and introducing timers or variable frequency drives can further reduce auxiliary loads. Overall, these combined measures could realistically reduce electricity consumption in audited TMC buildings by 25–35 percent, with simple payback periods ranging between 2–5 years for major equipment upgrades.

The behavioural assessment shows that human practices significantly influence energy use. Across most facilities, lights, fans and air conditioners are commonly left on in unoccupied rooms; curtains are often kept closed during the day (notably at Vartaknagar), limiting daylight use; and appliances remain plugged in or powered on even outside working hours. Only a minority of staff members report knowing their facility's electricity costs, and none have received formal energy-saving instructions or training. However, interviews reveal strong willingness to change practices: staff express enthusiasm for clear guidelines, energy-saving reminders, simple standard operating procedures, building-level competitions and recognition-based incentives. Nearly all respondents believe that their individual behaviour can reduce energy use, suggesting a strong foundation for an institutionalised behavioural change programme. Behaviour-driven measures alone, such as better switch-off discipline, optimised AC setpoints in the 24–26°C range, improved daylight utilisation and structured end-of-day shutdown routines, can reasonably deliver 5–10 percent energy savings at negligible cost, while also enhancing indoor comfort, extending equipment life and improving the reliability of critical services.

Rooftop solar potential across the Thane municipal portfolio is significant. Beyond the existing 25 kW system at the Vartaknagar Ward Office and the rooftop solar installation at School No. 53, phase-1 assessments identify roughly 165 kWp of additional PV capacity across three priority facilities: Cluster Cell Office (77.7 kWp), Tulshidham B2 BSUP (7.6 kWp) and Wagle Bus Depot (79.9 kWp). When implemented, these systems are expected to meet approximately 65–70 percent of each building's annual electricity demand, substantially reducing grid consumption, stabilising electricity costs and delivering durable greenhouse gas emission reductions from TMC's own operations.

If Thane implements the recommended combination of technical, behavioural and institutional measures, the audited facilities could collectively achieve 25–35 percent reductions in electricity consumption, with 5–10 percent attributable purely to behavioural change. This would translate into hundreds of thousands of kilowatt-hours saved annually and significant reductions in municipal electricity expenditure. Beyond the measurable benefits, the proposed actions would improve comfort, reduce operational risk associated with ageing equipment, strengthen municipal capacity for energy management and position Thane as a leader in sustainable municipal infrastructure.

To realise these outcomes, the report proposes a phased implementation roadmap. A short pilot phase (3–6 months) would deploy bundled interventions in one large administrative building and one community facility to refine procurement and operational processes. A second phase (6–18 months) would scale proven interventions across all audited buildings using standardized, high-efficiency procurement aligned with BEE 5-star and ECBC guidelines. In parallel, TMC should establish a formal Energy Management Cell, issue building-level SOPs, institutionalise recognition-based behavioural programmes and develop bilingual communication materials to reinforce energy-conscious practices. With consistent implementation, these measures will generate long-term energy savings, enhance service delivery quality and position Thane as a leading example of municipal energy efficiency and climate-responsive urban governance.

Introduction to the Study

Project Objective

The primary objective of this project is to advance the decarbonisation of municipal operations in Thane by:

- Reducing electricity consumption in key TMC buildings through energy efficiency measures and improved operational practices;
- Designing and initiating a behavioural energy-efficiency programme tailored to municipal staff; and
- Accelerating rooftop solar adoption across a representative set of municipal facilities.

The approach integrates:

- Building-level energy audits to identify technical inefficiencies, quantify baseline performance and prioritise improvement opportunities;
- Behavioural assessments to understand everyday practices, awareness levels and barriers to efficient energy use among TMC staff;
- Bilingual awareness and engagement tools (Marathi / Hindi / English) to ensure broad participation and ownership across departments; and
- A high-level rooftop solar roadmap aligned with local technical, regulatory and financial conditions, including MERC net-metering provisions and applicable state and central schemes.

The project is designed to support TMC's commitments under the Majhi Vasundhara Campaign, national missions on energy efficiency, and Maharashtra's renewable energy and climate targets, while contributing to Thane's broader resilience and low-carbon development strategy.

Project Scope

The scope of work includes:

- Conducting walk-through and semi-detailed energy audits for nine priority TMC facilities covering major administrative, social and infrastructure functions;
- Reviewing electricity consumption data, operating hours, occupancy and functional characteristics for each building to derive Energy Performance Index (EPI) benchmarks;
- Carrying out behavioural surveys, interviews and on-site observations with staff, facility managers and operators to map current practices and motivators;
- Developing and testing a behavioural change framework suitable for municipal workplaces in Thane;
- Screening rooftop solar feasibility at each audited site and aligning proposals with current MERC net-metering regulations and subsidy programmes; and
- Preparing a set of strategic recommendations and an implementation roadmap that is practical, scalable and aligned with BEE guidelines, ECBC provisions and ISO 50001 concepts where relevant.

While this Deliverable focuses on diagnostics and planning, the intent is to generate replicable technical and behavioural models that can be extended to other TMC buildings and, over time, inform initiatives with residential and commercial consumers within the city.

Audit Coverage

The energy audits encompassed nine municipal facilities in Thane, covering administrative, educational, healthcare, residential, sports and transport-related buildings. These include: TMC Main Office (Pachpakhadi); Cluster Cell Office (Wagle Estate); Vartaknagar Ward Office (including the municipal environmental laboratory); Swa. Meenatai Thakare Maternity Home (Dialysis Centre, D'Souza Wadi); Tulshidham B1 and B2 BSUP residential towers (common areas), Ghodbunder Road; Dadoji Kondev Stadium building, Naupada; Wagle Bus Depot, J.B. Sawant Marg, Wagle Estate; TMC School No. 53, Patlipada; and TMC School No. 55, Azadnagar, Kolshet Road.

These sites represent a cross-section of TMC's building stock and were selected for their significant electricity consumption, critical service functions or high demonstration potential for the wider municipal portfolio. Each audit involved on-site inspections during normal operating hours, basic electrical measurements where feasible, detailed equipment inventories, and analysis of available utility bills to establish baseline energy performance and indicative end-use breakdowns.

Methodology

As part of this study, the project team carried out both technical energy audits and a user-behaviour assessment across selected TMC buildings to understand not only how much energy is used, but also how and why it is used. The technical component focused on walk-through and semi-detailed audits to document equipment, operating schedules and consumption patterns at each site, while the behavioural component used staff surveys, interviews and on-site observations to capture everyday practices, awareness levels and barriers to efficient use of lights, fans, ACs and other equipment. The subsections below describe the approach to the walk-through energy audits and subsequent data analysis; the behavioural survey methodology is outlined in a separate section.

Energy Audits Methodology

Walkthrough Energy Audits

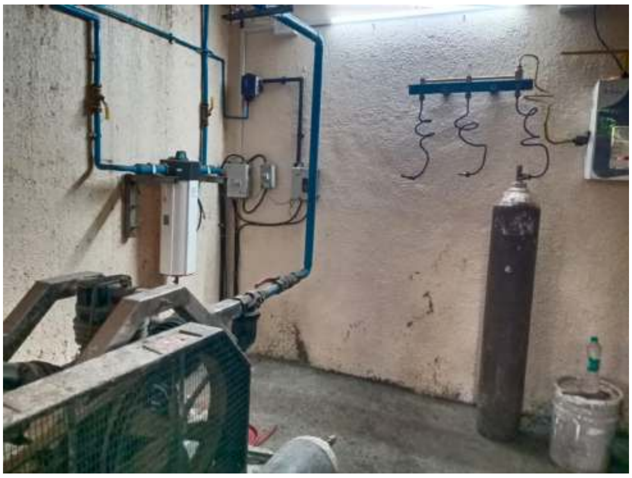
The energy audits followed a systematic procedure broadly aligned with BEE guidelines for walk-through and detailed audits. For each building, the audit team first gathered preliminary information, including floor plans where available, equipment inventories and past electricity bills. Surveyors then conducted on-site walkthroughs to observe all major energy-consuming systems: lighting (fixture types, densities, typical operating hours), HVAC (number, capacity and star rating of AC units, thermostat settings, zoning and controls), motors and pumps (horsepower ratings, operating schedules, automation status) and other appliances (computers, printers, laboratory equipment, refrigerators, workshop machinery, etc.). Facility managers and key staff were interviewed to clarify operational schedules, maintenance practices and known problem areas such as frequent breakdowns, comfort complaints or visible wastage. Each audit culminated in a building-specific summary of baseline conditions and a list of indicative technical measures tailored to that facility

Figure 1: Field Visits

Cluster Cell

Tulshidham BSUP B1/B2 residential towers

Dadoji Kondev Stadium



Meenatai Thakre Maternity Home

TMC Main Office

TMC School no.53

TMC School no.55

Wagle Bus Depot

Data Analysis

The analysis phase focused on organising and interpreting information collected during site visits and from utility bills. For each building, monthly and annual electricity consumption data (where available) were collated and combined with gross floor area to calculate the Energy Performance Index (EPI, $kWh/m^2 \cdot year$). These EPIs were then compared with indicative benchmarks from national studies and BEE/ECBC guidance for comparable building types (offices, schools, healthcare, residential common areas, sports facilities, depots) to understand relative performance.

End-use patterns (lighting, HVAC, water pumping, workshop equipment, plug loads and special equipment such as laboratory devices) were estimated using a combination of equipment inventories, nameplate ratings and broad area-based or time-based approximations rather than detailed sub-metering. For key systems such as ACs, lighting and fans, the team estimated the proportion of total floor area served (for example, share of office space that is air-conditioned versus naturally ventilated) and combined this with reported or typical hours of use from facility staff. Simple spreadsheet models were then used to group loads by category and derive order-of-magnitude estimates of their contribution to overall electricity demand, helping to identify dominant drivers such as cooling in administrative buildings and workshops, corridor and office lighting, water pumping in high-rise housing, and event-linked loads at the stadium.

Potential savings from efficiency measures were estimated using published performance data for higher-efficiency technologies (e.g. LED lighting, BEE 5-star inverter ACs, IE3/IE4 motors, high-efficiency pumps) and typical savings ranges from comparable case studies, rather than detailed equipment-level simulations. Lighting retrofits were assumed to deliver approximately 40–50 percent reductions in connected lighting load, while high-efficiency HVAC upgrades were assumed to reduce cooling electricity use by around 20–30 percent, consistent with benchmark studies. For motors, pumps and compressors, savings were estimated based on typical efficiency gaps and expected runtime reductions from timers or improved controls. Where greenhouse gas implications were needed, a standard grid emission factor was applied to estimated energy savings to derive indicative CO_2 reductions. These analyses fed into a prioritised set of recommended measures for each facility, with indicative savings ranges, investment levels and simple payback periods intended as planning guidance rather than detailed engineering design.

Accuracy and Limitations

During the energy audits conducted across TMC offices and facilities, several practical constraints affected the depth and precision of the assessment. In some buildings, complete access to all areas and fully up-to-date equipment lists was not available, while operational schedules and maintenance records were sometimes incomplete or informally maintained. The absence of sub-metering or real-time monitoring meant that end-use loads (for example, disaggregating lighting from cooling or plug loads) had to be inferred from spot measurements, nameplate ratings and assumed hours of use rather than direct measurement.

Because the audits were primarily walk-through in nature, site visits were time-bound and provided only a snapshot of operations; seasonal variations and shift-based load patterns therefore had to be inferred from monthly bills and interviews instead of continuous monitoring. In a few facilities, outdated or unlabelled electrical infrastructure complicated efforts to build a fully granular load inventory, and smaller plug loads could not be individually measured within available time. One priority facility, Chhatrapati Shivaji Maharaj Hospital, Kalwa, could not be audited due to limited departmental cooperation, creating a gap in direct hospital-level data; hospital-related insights in this report are therefore extrapolated from the Swa. Meenatai Thakare Maternity Home and comparable studies.

These constraints, which are typical in municipal contexts, introduce a reasonable margin of uncertainty around baseline EPI values and end-use breakdowns. However, cross-checking utility bills, field observations and staff inputs provides a sufficiently robust basis to identify major inefficiencies, estimate realistic savings ranges and prioritise practical, low-cost technical and behavioural interventions across the TMC portfolio.

Behavioural Assessment Methodology

Survey Design

To understand the behavioural dimensions of energy use in TMC facilities, a concise survey and interview guide was developed for building occupants across the nine audited sites. Approximately 40–50 staff members from administrative offices, the maternity home, the schools, the depot, the stadium and the residential complex participated, responding to a mix of multiple-choice and open-ended questions. The survey explored awareness of energy conservation practices, individual habits (such as switch-off routines and thermostat preferences), perceived barriers to energy-saving actions and suggestions for improving day-to-day operations. Questions were designed to be anonymous and non-judgemental to encourage honest feedback. In addition to self-administered questionnaires, semi-structured interviews were conducted with facility managers and a small number of frontline staff in each building, following a common checklist covering daily routines, roles and responsibilities, past initiatives and operational challenges that may influence energy practices. This combined instrument provided a structured but flexible framework for capturing behavioural insights alongside the technical audit.

Data Collection

The behavioural survey was administered during site visits to all nine facilities. Staff completed the questionnaire in paper form while the audit team was on site, with responses collected immediately to maximise completion rates. In parallel, observational data were gathered through walk-throughs to record actual practices. For example, whether lights and fans were switched off in unoccupied rooms, how corridor lighting was operated, how ACs were set and used during working hours and breaks, and how curtains or blinds were managed in daylit spaces. The team also checked for any existing circulars, notices, posters or signage related to energy saving; none were observed in the audited buildings, confirming the absence of prior structured campaigns. All survey responses were compiled into a simple database and grouped by building type (administrative offices, healthcare, education, residential common areas, sports and transport), while interview notes and field observations were collated as qualitative evidence to contextualise the numerical results.

Analytical Tools

The analysis of behavioural data relied on basic descriptive methods rather than complex statistical modelling. Survey responses were summarised as counts and percentages to identify common patterns in awareness, habits and perceived barriers. For example, the share of respondents who report routinely switching off lights and ACs when leaving a room, or who are aware of recommended thermostat setpoints. Open-ended responses and interview notes were reviewed to extract recurring themes such as discomfort concerns, perceived lack of authority to change settings, workload pressures or absence of clear guidance. Observational notes from walk-throughs were used to crosscheck self-reported behaviours, for instance, comparing claimed shutdown practices with the actual number of workstations, lights or fans left on after hours. Buildings were then compared qualitatively to identify where relatively better practices or stronger local leadership appeared to be present (for example, facilities where staff had informally adopted stricter switch-off routines). The objective was not to produce statistically precise scores for each building, but to synthesise multiple lines of evidence into a coherent picture of the main behavioural drivers of energy use in TMC's municipal buildings.

Baseline Behaviour Metrics and Reliability

The behavioural surveys and on-site assessments provided an indicative baseline of current energy-use practices in the audited TMC buildings. After-hours shutdown emerged as a key concern: in several administrative areas and at Wagle Depot, a noticeable share of desktop computers, fans and some lights remained on or in standby mode at the end of the workday, indicating inconsistent adherence to switch-off routines. Corridor and common-area lighting was generally operated manually with limited use of zoning or sensors; in many cases lights were switched on at the start of the day and left on for extended periods regardless of occupancy or daylight availability. Thermostat settings for air-conditioned spaces were frequently observed around 22–24°C in offices and the maternity home, below the 24–26°C range typically recommended for comfort cooling in warm-humid climates, pointing to habitual over-cooling and associated excess energy use.

Awareness levels were mixed. While most respondents agreed that saving electricity is important, relatively few could readily identify specific, workplace-relevant actions such as optimising AC setpoints, using natural daylight more effectively or consistently switching off appliances at the plug. At the same time, many staff members, particularly younger employees, expressed strong interest in awareness sessions, friendly energy-saving competitions and recognition programmes, suggesting significant latent willingness to engage. These findings establish a practical behavioural baseline against which future interventions can be designed and monitored, for example by tracking improvements in shutdown practices, thermostat settings and energy-specific awareness over time.

As with most behavioural assessments, there are inherent limitations in data reliability. Self-reported behaviour can be subject to social desirability bias, and the sample size and observation period are not intended to generate statistically representative scores for each site. To mitigate these issues, surveys were conducted anonymously and complemented with direct observations at different times of day, including near closing time, and interpretation focused on consistent patterns across multiple data sources rather than individual responses. Behaviour is also likely to vary seasonally and with changes in staffing or workload. For these reasons, the current findings are treated as indicative of typical practice during the audit period rather than an exact year-round average. Despite these constraints, the convergence of evidence from surveys, interviews and on-site observations provides reasonable confidence that the key behavioural issues identified, over-cooling, inconsistent switch-off practices and limited prior guidance, are systemic and material for TMC's buildings, and that they provide a robust starting point for designing and later refining the behavioural change programme.

Baseline Energy and Operational Data

Overview of Baseline

Baseline data was collected to establish the reference energy performance of TMC buildings before any new interventions. This includes electricity consumption (from utility bills), operating hours, occupancy and facility size (floor area) for each audited site. The baseline serves as the yardstick against which improvements from technical upgrades, behavioural measures and rooftop solar will be measured. In summary, the baseline assessment confirms that current energy use in the nine representative TMC facilities is significant relative to their functions, indicating substantial opportunity for savings through the strategies outlined in this report.

Data Collection

Surveyors gathered utility electricity bills for each audited building for the past 12 or more months wherever available, in order to capture seasonal variations in consumption. For example, monthly kWh data for 2023–24 were collated for major offices, the maternity home, the depot and the stadium. Where backup diesel generators exist (e.g. at the maternity home and stadium), any available fuel consumption data were compiled to understand total energy use, although the primary focus of this study remains grid electricity. Gross floor area figures for each building were provided by TMC's relevant departments or, where recent drawings were unavailable, were measured during site visits (using tapes or laser distance meters) and checked against satellite imagery. Operational schedules were documented for each facility, for example: administrative offices typically operating 8–10 hours per weekday, the maternity home operating 24×7, schools operating 6–8 hours on school days, Wagle Bus Depot operating on a mixed office plus shift basis, and Dadoji Kondev Stadium running on an office plus event-driven schedule. Where exact data (such as real-time occupancy profiles) was not available, best estimates based on design capacity, typical utilisation and staff inputs were used. All baseline information was tabulated for clarity in supporting appendices.

Baseline Data Tables

Table 1 summarises the key baseline metrics for the audited TMC buildings, using the revised EPI values and performance bands:

Table 1: Key Baseline Metrics

Sl. No	Building	Use	EPI (kWh/m²·yr)	Performance Band*	Key Focus Area

1	Thane Municipal Corporation HQ	Admin Office	66.85	Moderate–Low	Already better than typical offices – improve HVAC discipline, night shut-off
2	Vartaknagar Ward Office, TMC	Admin Office	37.81	Low	Net-low EPI (with solar) – maintain good practice, use as showcase site
3	Cluster Cell Office, TMC	Admin Office	27.12	Low	Very efficient – focus on occupancy sensors and plug-load management
4	Tulshidham B2 Building (BSUP, common)	Residential common areas	≈3.8	Very Low	Pump timers/level controllers, sensor lights, small common-area solar
5	Wagle Bus Depot (Admin + Workshop)	Transport depot / workshop	28.85	Low	Safety fixes, compressor/pump control, then rooftop solar

**(Notes: EPI = Energy Performance Index, i.e. kWh per square metre per year. For mixed-use sites such as Wagle Bus Depot, EPI is calculated on total built/covered area, and is not directly comparable to purely enclosed office buildings.)*

These figures show that the TMC Headquarters is the single largest consumer in absolute terms, with annual electricity use of the order of 1.2 million kWh, while Cluster Cell and Vartaknagar Ward Office form an efficient but still improvable cluster of administrative buildings. Tulshidham B2's common areas have a very low EPI due to limited conditioned space and modest common-area loads, whereas Wagle Bus Depot's EPI reflects the combined effect of ageing HVAC, workshop equipment and structural deficiencies that increase cooling demand. This baseline table is used to prioritise interventions (for example, focusing first on high-consumption and moderate-EPI offices and on the depot's safety-critical envelope) and to set realistic performance targets, such as progressively reducing EPI values for the main office and depot while maintaining or further improving low-EPI sites like Cluster Cell and Vartaknagar.

Energy Use Breakdown

Where possible, energy consumption by end-use category was broken down for each TMC building using equipment inventories and typical usage profiles. In large administrative offices such as TMC HQ and Cluster Cell, a substantial share of electricity is attributed to HVAC (AC units and fans), typically followed by lighting and IT equipment (computers, printers, servers), with the remainder going to lifts, pumps and miscellaneous appliances. In the maternity home, a higher portion of the load is associated with continuous HVAC operation and essential medical equipment, while in schools the dominant loads are classroom lighting and fans during daytime hours, with relatively low plug loads. At Wagle Bus Depot, workshop equipment (compressors, welding machines, grinders) constitutes a significant share of daytime consumption in addition to office HVAC and lighting, whereas the stadium's profile is strongly event-driven, with large spikes from floodlighting and hall conditioning during matches or functions and much lower baseline demand on non-event days.

These end-use breakdowns, though approximate, are essential for targeting measures: for example, knowing that cooling and IT together dominate office loads indicates that AC optimisation and plug-load management will yield larger savings than lighting retrofits alone, while in the depot, compressor control and safety-driven envelope repair become early priorities. Temporal patterns were also noted. Offices and schools display a pronounced drop in consumption at night and on weekends (apart from security and emergency lighting), whereas the maternity home has a nearly flat 24-hour load profile characteristic of continuous healthcare operations. Seasonal variation is visible in most buildings, with higher consumption in the summer months (April–May) due to increased cooling loads and somewhat elevated lighting hours, and modest reductions during the monsoon when ambient temperatures are lower.

Notable Patterns

A few patterns stand out in the revised baseline data. First, among the audited buildings, TMC Headquarters remains the largest single energy user, but its EPI now falls in a moderate–low band, suggesting that while the building is not excessively wasteful per square metre, its large size and intensive equipment use still make it a priority for savings. Second, Cluster Cell and Vartaknagar Ward Office exhibit comparatively low EPIs, with Vartaknagar's net EPI substantially reduced by its 25 kW rooftop solar installation, indicating that combined efficiency and on-site generation can deliver near "showcase" performance even in conventional office buildings. Third, Tulshidham B2's very low EPI confirms that common-area loads in residential towers are modest in absolute terms, but its pumping and corridor lighting systems still offer clear opportunities for automation and small-scale solar. Finally, Wagle Bus Depot's moderate EPI, when viewed alongside its documented safety and envelope issues, points to a dual agenda of risk reduction and energy efficiency, rather than purely technology-focused retrofits. The absence of interval metering and detailed peak demand data limits the ability to quantify load factors and base-load components precisely, underlining the importance of better metering and monitoring in subsequent phases.

Assumptions in Baseline Data

Several assumptions were necessary in compiling the baseline due to data limitations. It was assumed that electricity billing units correspond directly to kWh and that power-factor corrections do not materially affect kWh values for the purposes of this analysis, as bills are primarily based on kWh/kVAh and observed penalties were minor. For most buildings, 12 consecutive months of electricity bills were available; where only partial data existed, indicative annual figures were derived by extrapolating from the available months and clearly treated as approximate. Floor area measurements for some older or complex facilities (for example, the depot and stadium) did not always have updated drawings and were therefore estimated using on-site measurements and cross-checks against satellite imagery, resulting in an estimated uncertainty of around ±10 percent in area and derived EPI values.

Where detailed utilisation data (such as hourly occupancy or event frequencies) was not available, typical or reported patterns were used, e.g. average school-day operation for classrooms, standard office hours for administrative spaces, and representative event schedules for the stadium, recognising that actual year-to-year variation may occur. End-use breakdowns (HVAC, lighting, plug loads, pumps, special equipment) relied on typical percentage shares from published studies for comparable Indian buildings and were cross-checked against observed equipment inventories and any partial sub-meter readings shared by TMC staff. No explicit weather normalisation was applied; the baseline reflects actual consumption in the assessment year, with the understanding that unusually hot or mild seasons can influence cooling loads. These assumptions primarily affect the precision of individual metrics rather than overall trends, and they do not alter the key conclusion that there is substantial, system-wide scope for energy efficiency improvements and rooftop solar integration across the audited TMC buildings.

Detailed Findings from Audits and Assessments

Energy Audit

Baseline Data

Across the audited TMC facilities, the equipment mix and operating profiles vary by building type but tell a consistent story of significant cooling, lighting and auxiliary loads with clear scope for optimisation. Administrative buildings (TMC Headquarters, Cluster Cell and Vartaknagar Ward Office) rely on large numbers of 2–3 star split and window AC units, dense fan distributions and extensive IT equipment, with ACs often operated "as required" at 22–24°C and limited use of zoning, timers or occupancy-linked controls. Wagle Bus Depot combines office spaces with a workshop and traffic control functions, adding compressors, pumps and welding equipment to the base office loads, while also facing serious electrical safety and envelope issues, open wiring, broken windows and envelope cracks, that raise both risk and energy demand.

Educational buildings (Schools 53 and 55) operate mainly with fans, tube lights/LEDs and modest IT loads during school hours, but with limited active management of fans and lights at recess or after class; the main opportunity is to strengthen switch-off discipline among staff and students. Swa. Meenatai Thakare Maternity Home exhibits a typical 24×7 healthcare profile with a high proportion of area under air-conditioning, continuous use of critical equipment and limited flexibility for shutdowns, yet retains significant potential for improved zoning, smart thermostat control and separation of clinical and administrative zones. In Tulshidham BSUP towers, common-area loads are dominated by water pumping and circulation lighting, both of which are presently controlled manually. At Dadoji Kondev Stadium, small office and gym loads are overshadowed by event-driven peaks from lighting and HVAC during functions, underscoring the importance of event-based scheduling and efficient luminaires.

Baseline Performance

Baseline electricity consumption across the nine facilities is substantial, with offices and the maternity home dominating annual kWh use. TMC Headquarters alone consumes around 1.2 million kWh per year, while Cluster Cell, Vartaknagar Ward Office and Wagle Bus Depot together add roughly a few hundred thousand kWh more, even before accounting for the broader municipal portfolio. Although revised EPIs for most administrative buildings now fall in the low to moderate–low range, overall performance remains below best-practice benchmarks for ECBC-aligned or BEE 5-star buildings in similar climates. The maternity home's estimated EPI, while inherently higher due to 24×7 clinical operations, also indicates scope for HVAC optimisation and targeted end-use control in non-clinical spaces.

A consolidated snapshot of building-wise characteristics and priorities is provided below.

Table 2: Key Observations from Energy Audits – TMC Buildings

Category	% AC-Covered	Key Issues and Immediate Priorities
Admin (TMC, Cluster, Ward)	60–70%	**Key Issues** Unscheduled AC use, low daylight utilisation, persistent idle IT loads **Immediate Priorities** AC zoning and timers, daylight use, plug-load control, solar expansion
Transport (Wagle Depot)	30%	**Key Issues** Electrical safety gaps, compressor/pump overuse, no solar installation **Immediate Priorities** Wiring and envelope repair, maintenance log, rooftop solar setup
Education (Schools 53 & 55)	<10%	**Key Issues** Fans/lights unmanaged, ageing wiring in places **Immediate Priorities** Smart switches, BLDC fans, basic rewiring, awareness campaigns
Healthcare (Maternity Home)	~90%	**Key Issues** High 24/7 HVAC load, limited zoning and temperature discipline **Immediate Priorities** Smart thermostats, zonal setpoints, sub-metering and energy tracking
Residential (BSUP – common)	~10% (common)	**Key Issues** Manual pump operation, no sensors, limited daylight-linked control **Immediate Priorities** Auto-timers/level controllers, LED retrofits, resident engagement
Sports (Stadium building)	~30%	**Key Issues** Event load mismanagement, legacy halogen and decorative lighting **Immediate Priorities** Lighting zoning, timers and event-mode controls, solar adoption

Coverage (Thane): TMC Main Office, Cluster Cell (amenity building), Vartaknagar Ward Office, Wagle Bus Depot (admin/traffic/workshop), Dadoji Kondev Stadium Building, TMC Schools 53 & 55, Swa. Meenatai Thakare Maternity Home, and Tulshidham BSUP B1/B2 residential towers.

HVAC is the dominant controllable load in the main offices, stadium building and maternity home, with many units still 2–3 star or older, a mix of split/window/ducted systems, and limited use of setpoint discipline or runtime controls. Lighting is largely based on LEDs and tube lights, but daylight is systematically under-utilised in some offices (notably at Vartaknagar, where curtains remain closed during working hours), and corridor/common-area lights are often run on fixed manual routines. Pumps and specialty equipment, laboratory devices at Vartaknagar, workshop tools and compressors at Wagle, contribute meaningful non-HVAC loads during office or shift hours. Overall asset condition is generally safe and operational, with the notable exception of Wagle Depot, which shows open wiring, damaged windows and envelope cracks that present both safety and efficiency risks. Rooftop solar is installed only at Vartaknagar (25 kW, grid-connected, actively offsetting consumption); arrays are physically present but not fully connected or documented at TMC Headquarters and School 55, and absent at Wagle, the stadium, School 53 and the maternity home at the time of the audit.

Identified Inefficiencies

The audits uncovered a range of inefficiencies.

Lighting

In administrative buildings and the stadium, lights in corridors, stairwells and some work areas were frequently observed operating even under adequate daylight and low occupancy, reflecting a lack of zoning, sensors and switch-off discipline. At schools and in BSUP common areas, fans and lights are routinely left on during recess or between classes, as responsibility for shutdowns is diffuse and there are no visual cues or student-monitor systems in place.

HVAC

Air-conditioning loads are a central driver of inefficiency. At TMC Headquarters, 152 mostly 2–3 star AC units operate with decentralised, manual control; setpoints are commonly in the 22–24°C band and many zones run ACs and fans simultaneously throughout office hours regardless of occupancy. Cluster Cell and Vartaknagar show similar, though somewhat better-managed, patterns, with multiple split and central units serving offices and library or lab spaces without building-wide scheduling. At Wagle Depot, large numbers of window ACs cool partially enclosed spaces with broken glazing and envelope cracks, significantly increasing cooling load for limited comfort gain. In the maternity home, continuous HVAC operation is clinically necessary in key areas, but administrative and waiting zones still lack differentiated setpoints and schedules.

Equipment & Appliances

Miscellaneous loads across buildings are frequently sub-optimised. Office IT equipment, PCs, printers, scanners, photocopiers, TVs and routers, was often observed powered on or in standby after working hours, creating a non-trivial idle base load in administrative facilities and the stadium. Water pumps in Tulshidham BSUP towers and at Vartaknagar operate on manual control without level sensors or timers, leading to longer than necessary runtimes. Laboratory and workshop equipment (e.g. hot air ovens, COD digestors, spectrometers at Vartaknagar; compressors and welding sets at Wagle) are run on simple on/off practice with limited load-based control.

Power Factor & Distribution

While core electrical infrastructure is broadly adequate, fine-grained control is often lacking. Circuits for lighting and AC are not zoned to match occupancy patterns in several buildings, so large sections must be energised even when only a subset of rooms is in use. There is very limited use of automated controls such as programmable timers, occupancy sensors, daylight sensors or event-mode presets, which reduces the ability of staff to manage loads efficiently.

Quantitative Results and Potential Savings

Using the revised baseline, the audits quantified the technical savings potential from a bundled set of interventions across the TMC facilities. Full LED conversion and better controls (occupancy sensors, timer-based outdoor and corridor lighting, event-mode circuits for the stadium and high-use halls) are expected to reduce lighting loads by about 40–50 percent across the portfolio, saving tens of thousands of kWh annually. HVAC-related measures, phasing out old 2–3 star split/window units in offices and the maternity home in favour of BEE 5-star inverter ACs, enforcing 24–26°C setpoints, introducing basic zoning and scheduling, are estimated to deliver around 20–30 percent reductions in cooling energy, particularly at TMC Headquarters, Cluster Cell and Swa. Meenatai Thakare Maternity Home where cooling is the dominant controllable end-use.

Additional savings can be realised by replacing ageing fans, pumps and workshop motors with high-efficiency IE3/IE4 models and installing timers or variable-speed drives where operating profiles justify them, notably in BSUP pump systems, depot compressors and selected administrative water systems. While detailed cost–benefit analysis for TMC is still being refined, experience from the Navi Mumbai portfolio suggests that such a package can typically deliver 25–35 percent overall electricity savings with simple payback periods in the 2–5 year range: lighting retrofits around 2 years, AC replacements 3–5 years and pump/VFD upgrades roughly 4 years.

Potential Improvements and Compliance

If these measures are adopted at scale, the audited TMC facilities can expect significant reductions in EPI, particularly in high-consumption offices and the maternity home, moving them closer to or within ECBC-aligned performance ranges for public buildings in warm–humid climates. However, as at present most buildings do not meet BEE 5-star thresholds at either whole-building or equipment level, a key recommendation is that TMC adopt a green procurement policy requiring that all new energy-consuming equipment be of the highest available efficiency class (e.g. BEE 5-star or equivalent) and that retrofits explicitly reference ECBC and BEE guidance.

Behavioral Assessment Findings

Assessment Process

A behavioural energy-use assessment was conducted in all nine audited TMC buildings through site visits, short staff surveys and semi-structured interviews with facility managers, technical staff and, where relevant, residents. The assessment team observed how and when lights, fans, ACs, pumps and equipment were switched on and off during the working day, and whether appliances were left running in unoccupied spaces. Survey questions covered awareness of building-level electricity costs, receipt of energy-saving instructions from management, self-reported switch-off habits, and preferred motivators for participating in energy-saving efforts. Existing signage, circulars or reminders related to electricity saving were also reviewed to check whether any past campaigns or formal guidance had been issued.

Current Practices & Gaps

The current energy-use practices in audited TMC buildings deviate markedly from good-practice norms, despite generally positive attitudes towards saving electricity. Across the main office, Cluster Cell, Wagle Bus Depot, Dadoji Kondev Stadium, the maternity home and Tulshidham BSUP, survey respondents consistently reported "sometimes" switching off lights, fans and equipment when leaving a room, and site observations confirmed that in several facilities, lights and fans were left on in unoccupied rooms and corridors. At the maternity home, some lights and fans were observed in empty rooms and ACs were controlled only via remotes while the main switches remained on; at Tulshidham, residents reported that water pumps are often left running for 3–4 hours before being switched off. In TMC Headquarters, Cluster Cell and Wagle Depot, multiple appliances were seen left plugged in and sometimes powered on in unoccupied rooms, reflecting weak end-of-day shutdown discipline.

- **Daylight and AC practices also show inefficiencies.** At Vartaknagar Ward Office, for example, office window curtains were routinely kept closed during the day, preventing daylight entry and driving unnecessary use of LED lighting. In several offices and the stadium building, staff acknowledged that appliances were left on in unoccupied rooms and that setpoints and operating hours were not actively managed for efficiency. None of the surveyed TMC buildings reported structured energy-saving campaigns or systematic past training, and reminder signage (near switches or AC controls) was largely absent. Because electricity bills are paid centrally and are rarely shared with facility staff, most respondents either did not know or were unsure about their building's monthly electricity costs, which further weakens perceived accountability.

- **Staff Survey Insights and Implications.** Survey responses from Thane facilities show a common pattern: almost all respondents "agree" that their individual role can help reduce building energy use, but concrete practices have not yet caught up with this belief. In the TMC Main Office, both the field assistant from the Pollution Control Department and the electrical technician agreed that their actions matter and suggested switching off appliances when not in use and adopting energy-efficient equipment, yet both noted that some appliances were left on in unoccupied rooms. At Cluster Cell, the office attendant similarly reported appliances left plugged in and lights left on when not needed, while recommending greater use of natural daylight and more consistent switch-off behaviour. At Wagle Bus Depot and Dadoji Kondev Stadium, staff recognised that fans and lights were left on in empty rooms and called for awareness sessions and visual reminders to change habits.

- **In the social infrastructure buildings, patterns are similar.** At Swa. Meenatai Thakare Maternity Home, the Medical Officer acknowledged that some lights and fans were left on in unoccupied rooms and that main AC switches remained on even when units were controlled via remotes, and specifically requested better instructions, awareness sessions and posters to remind staff and visitors to switch off when not in use. At Tulshidham BSUP, a resident noted that common pumps were left running for 3–4 hours before being switched off and suggested posters and occasional awareness sessions. In the two TMC schools, principals reported "no energy wastage observed" but still supported awareness sessions, LED use and visual posters, indicating openness to proactive engagement even where waste is not immediately visible.

- **Preferred Motivators and Programme Design.** Across all Thane respondents, recognition-based motivators and friendly competition consistently ranked higher than monetary incentives. Staff in Cluster Cell, Wagle Depot, Dadoji Kondev Stadium and TMC Main Office primarily selected "Recognition" or "Competition" as preferred motivators, proposing certificates, internal acknowledgement and contests, while respondents from the maternity home and Tulshidham BSUP highlighted "Better instructions" alongside visual prompts and awareness sessions. School leaders and several technical staff in Thane sites similarly favoured competitions and awareness, reinforcing the suitability of recognition-led approaches across both cities.

These insights suggest that a TMC behavioural programme should prioritise: clear, practical instructions on AC setpoints and shutdown routines; bilingual posters and stickers near switches, pumps and AC controls; simple end-of-day SOPs integrated into security or housekeeping rounds; and building- or floor-level recognition schemes (e.g. "Green Floor of the Month" or "Energy-Smart Ward Office") rather than financial rewards. Given that most staff already "agree" their role matters but currently follow "sometimes" switch-off routines, structured cues and social reinforcement are likely to be more effective than abstract appeals.

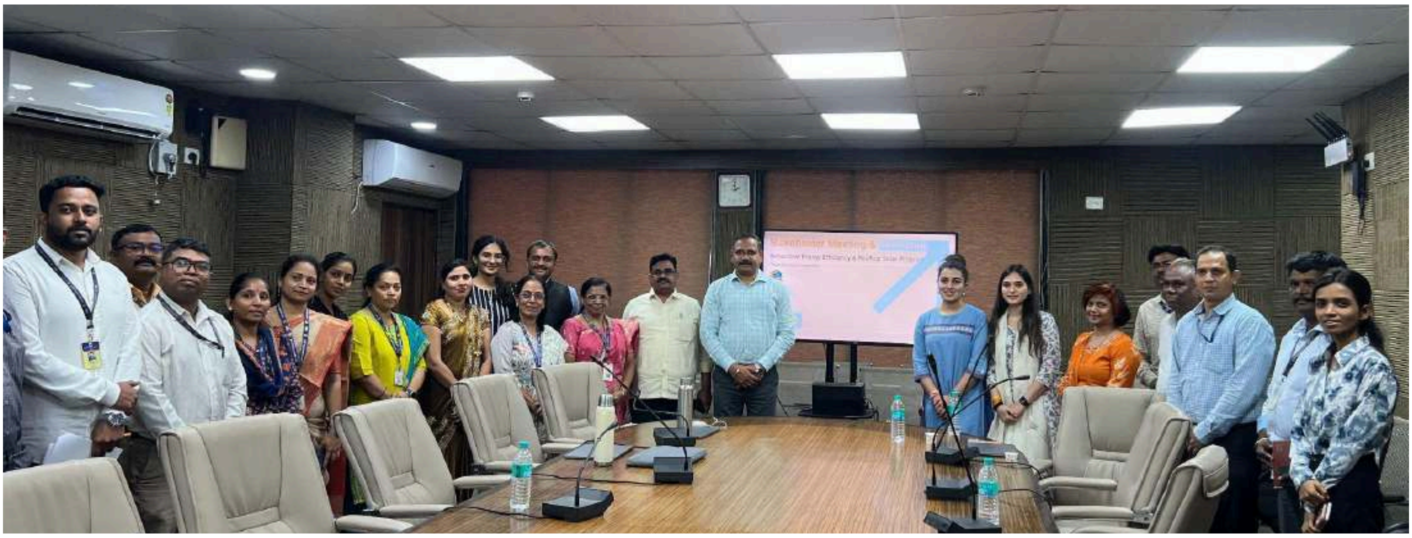
Behavioural Barriers and Impact Potential in Thane

The assessment highlights several behavioural barriers that need to be addressed in TMC buildings: split incentives (staff do not see or pay energy bills), comfort and convenience preferences (hesitation to adjust AC settings or turn off lights), informational gaps (limited understanding of how everyday actions sum to large energy use), and ingrained routines (fixed schedules for pumps and corridor lights). Hierarchical norms may also discourage some staff from changing settings in spaces used by senior officials. Addressing these barriers will require a combination of awareness-raising, simple procedural changes (e.g. last-person-out responsibilities, switch-off checks in security rounds) and low-cost technical enablers (timers, motion sensors, better zoning) so that efficient behaviour becomes the default rather than an exception.

Based on survey responses and international evidence, behaviour-driven changes alone, better switch-off discipline, improved daylight use in offices like Vartaknagar, more careful pump operation in Tulshidham, and structured end-of-day shutdowns in TMC HQ, Cluster Cell, Wagle Depot and the stadium, can realistically reduce electricity consumption by around 5–10 percent across the audited Thane buildings, at negligible capital cost. In addition to direct kWh savings, reducing unnecessary runtime for lights, fans, ACs and pumps will extend equipment life, lower maintenance needs, and improve comfort by avoiding over-cooling and glare, while reinforcing TMC's public image as a climate-responsive municipal corporation.

Figure 2: Campaign Material to lead Behavioural Change

Strategic Recommendations and Next Steps



In Picture: TMC Officials with representatives from C40 and SvaraScape at the Workshop conducted in November 2025

Energy Efficiency Interventions (Facility Upgrades & Operational Improvements)

Priority Measures

For Thane, priority technical measures focus on the nine audited TMC facilities: TMC Main Office, Cluster Cell, Vartaknagar Ward Office, Wagle Bus Depot, Dadoji Kondev Stadium, Schools 53 and 55, Swa. Meenatai Thakare Maternity Home, and Tulshidham BSUP towers. These buildings show dominant loads from HVAC, lighting, pumps and IT/workshop equipment, with many 2–3 star ACs, extensive fans, unscheduled pump operation and under-used daylight in key offices such as Vartaknagar.

Key recommended interventions are:

- Complete LED retrofits and occupancy/daylight-based controls in offices, schools, stadium and common areas, addressing corridors, toilets, meeting rooms and gyms.
- Progressive replacement of old 2–3 star split/window ACs in TMC Main Office, Cluster Cell, Wagle Depot, Stadium and the maternity home with BEE 5-star inverter units, coupled with standardised 24–26°C setpoints and programmable thermostats.
- Zonal HVAC control in the maternity home, clearly separating clinical zones (tighter setpoints, 24×7) from administrative areas that can run at higher temperatures and reduced hours.
- Pump and motor optimisation through auto-stop controllers and, where justified, IE3/IE4 motors and VFDs, prioritising Vartaknagar's two 5 HP pumps, Tulshidham's shared pump system, and workshop compressors at Wagle Depot.
- Basic envelope and safety repairs at Wagle Depot (open wiring, broken windows, cracks) to cut infiltration-driven cooling loads and address critical safety risks.
- Standard high-efficiency procurement across TMC for all new ACs, fans, refrigerators, pumps and IT equipment, aligning with BEE 5-star / Energy Star specifications.

LED Colour Temperature & Visual Comfort

For Thane's warm–humid conditions, neutral "off-white" LEDs (about 3,500–4,000 K) are recommended in offices and most indoor workspaces, warmer whites in waiting or rest areas, and neutral-to-cool whites for high-precision lab or records work; energy use is driven mainly by wattage, so colour temperature should be chosen for comfort and task needs. Operating rules of thumb should be standardised across TMC facilities: switch LEDs, fans and small plug loads off whenever spaces are unoccupied, and avoid only very rapid cycling of ACs while switching them off for meaningful unoccupied periods or raising setpoints instead of running continuously at 22°C.

Operating Practices: Switching ON/OFF Lights and ACs

A recurring question during the audits was whether frequent switching of lights and ACs increases energy use or damages equipment. For modern LED lighting, the international evidence is clear: it is almost always better to switch lights off whenever a space is not in use. LEDs draw negligible extra energy at start-up and are designed for frequent switching; turning them off even for a few minutes of non-occupancy saves net energy and does not materially shorten lamp life (Fisk, 2016). This principle should be reflected in TMC's operating procedures and awareness messages ("If you leave the room, switch it off").

Global guidance suggests that even for such lamps, switching off when a room will be unoccupied for more than a few minutes is still beneficial from an energy perspective; the main consideration is maintenance planning as very rapid cycling can shorten lamp life. For air conditioners and larger motors, the practice is slightly different. Very rapid on–off cycling (for example, repeatedly switching a unit off and on within 3–5 minutes) can stress compressors and controls. However, for typical municipal use, switching ACs off for meaningful breaks (e.g. 20–30 minutes or more in offices, halls and meeting rooms) is preferable to leaving them running continuously, especially when rooms are unoccupied. In hospitals and other critical areas, thermal comfort and clinical requirements must be respected, but even there, raising setpoints to 24–26°C and switching off ACs in unused rooms or during cleaning periods are good practices. The recommended rule of thumb for TMC is:

- **Lights (especially LEDs):** switch OFF whenever a room is unoccupied.
- **Fans and small plug loads:** switch OFF whenever not needed.
- **ACs:** avoid very rapid cycling, but switch OFF for longer unoccupied periods; otherwise use thermostat adjustment (higher setpoint) rather than running continuously at 22°C.

These practices will be embedded in the proposed Standard Operating Procedures (SOPs) and reinforced through the behavioural change programme.

Implementation Plan

The implementation of these efficiency upgrades can be staged over the next 1–2 years.

Pilot Phase (next 3–6 months)

- Bundle LED, AC setpoint standardisation, pump auto-stop controllers and basic controls in two or three flagship sites, such as TMC Main Office and Wagle Depot (for safety plus efficiency), using them to refine specifications and vendor processes.

Phase 2 – Scale-up (6–18 months)

- Extend proven measures to Cluster Cell, Vartaknagar, Dadoji Stadium, Schools 53 & 55, the maternity home and Tulshidham, sequencing works floor-wise and avoiding disruption of core services.
- Use bulk procurement for LEDs, BLDC fans and inverter ACs to lock in prices and standardise product quality.

Project Management and M&V

- Establish an Energy Management Cell under the Chief Environmental Officer, with at least one full-time Energy Manager, to coordinate retrofits, rooftop solar, and behavioural programmes.
- Designate a Facility Energy Officer for each major building to track monthly kWh, supervise basic O&M, and liaise with Energy Champions.
- Install sub-meters where billing is centralised and track monthly EPI and cost savings, comparing against the audit baseline while qualitatively accounting for occupancy and seasonal effects.

Policy and Process Changes

TMC should formalise an energy policy that:

1. Mandates 24–26°C default AC setpoints, 5-star (or equivalent) ratings for all new energy-using equipment, and annual pre-summer HVAC servicing.
2. Embeds "last-person-out" shutdown checks, IT and plug-load switch-off protocols, and daylight-use guidance into standard operating procedures for all facilities.
3. Links energy performance to facility-manager KPIs, with annual targets for percentage reduction vs. baseline.

Capacity building should include bilingual (Marathi–English) training for electricians, facility managers and general staff on new systems and simple operational good practice, plus an Energy Champions network in each building to monitor habits, support data collection and lead local campaigns.

Rooftop Solar and Expected Impact in Thane

The audit identifies approximately 600–640 kW of feasible rooftop PV potential across the audited Thane buildings, with Vartaknagar's existing 25 kW system already offsetting roughly 43% of that site's annual consumption. Phased deployment should prioritise the highest-potential sites first: Cluster Cell Office (~77.7 kW), Wagle Bus Depot (~79.9 kW) and Tulshidham B2 BSUP (~7.6 kW), together representing about 65–70% of the total identified PV capacity, followed by TMC Main Office, additional capacity at Vartaknagar, Schools 53 & 55, the maternity home and remaining BSUP roofs, while leveraging state and central subsidies to target simple paybacks often under 2 years.

Across the audited Thane portfolio, the combined effect of technical retrofits, operational improvements and behavioural change is estimated to reduce electricity use by around 20–50%, equivalent to roughly 200,000–600,000 kWh per year and about 100–150 lakh rupees in annual savings once fully implemented. At typical grid emission factors, this corresponds to several hundred tonnes of CO_2 avoided annually, while also improving occupant comfort, reducing breakdowns in critical equipment and helping TMC visibly demonstrate municipal climate leadership.

Behavioral Change Program

Global Good Practices and Applicability to TMC

Experiences from cities and public institutions globally show that how people use buildings is as important as the technology installed in them, which is directly relevant to TMC's mix of large offices, schools, a maternity home, a stadium, a depot and residential towers. The audit and behavioural survey in Thane confirm that staff are generally motivated but lack clear goals, feedback and structures, exactly the gaps that global good practices address.

Clear goals, leadership signals and a shared story

Leading programmes set simple, public behaviour-linked goals backed by visible senior-level endorsement. For TMC, this could mean a corporation-wide commitment such as "reduce electricity use in key municipal buildings by 20–30% over five years," explicitly linked to staff actions like switch-off discipline, thermostat practices and efficient use of pumps and workshop equipment. The Chief Environmental Officer and senior leadership can reinforce this through periodic circulars, town-hall style briefings and by highlighting energy performance in routine review meetings.

Simple behavioural rules in hospitals: "TLC-style" campaigns

International experience shows that very simple, easy-to-remember rules work well in complex environments such as hospitals and large offices. For TMC, a concise three-point mnemonic in Marathi/Hindi/English can be adapted for the maternity home, TMC Main Office, Cluster Cell and Wagle Depot, for example:

1. Switch off lights/fans/ACs in unoccupied rooms (except where clinical readiness requires otherwise in the maternity home).
2. Use recommended AC setpoints of 24–26°C in administrative and public areas.
3. Open curtains/blinds in offices like Vartaknagar during the day and keep doors/windows managed to balance comfort and efficiency.

Posters, stickers at switches and quick reminders in staff briefings can anchor these rules in daily routines.

Figure 5: Campaign Material to lead Behavioural Change

Feedback, dashboards and “social comparison”

Global programmes use simple dashboards or “energy scorecards” in lobbies and intranets to show monthly consumption, progress against targets and whether performance is improving or slipping, often adding comparisons between buildings or floors to tap into friendly competition. For TMC this can translate into:

- A monthly one-page energy scorecard for each major facility (TMC Main Office, Cluster Cell, Vartaknagar, Wagle Depot, Dadoji Stadium, the maternity home, schools and Tulshidham), with kWh, approximate cost and change vs. baseline.
- A simple visual indicator (for example, green/amber/red symbol) to show whether the building is on track for its reduction target.
- Periodic recognition in internal communications for the “most improved building” or “greenest floor/department,” reinforcing positive norms.

Competitions, recognition and non-monetary incentives

Evidence from public-sector offices and universities shows that non-monetary recognition and friendly competition often motivate staff more effectively than small financial rewards. TMC’s own survey results echo this: most respondents across Main Office, Cluster Cell, Wagle Depot, Dadoji Stadium, schools and Tulshidham chose recognition or competitions, and none prioritised monetary incentives.

TMC can therefore:

- Run quarterly “Energy Saving Challenges” between ward offices, schools, the stadium, the depot and other facilities, based on percentage reduction vs. each site’s own baseline.
- Offer certificates, plaques, internal newsletter features and public acknowledgment from the Municipal Commissioner for top performers rather than cash rewards.
- Highlight both percentage and absolute kWh savings to keep smaller but efficient buildings (e.g. Vartaknagar, Schools 53 & 55) engaged.

Figure 6: Complete to Conserve Challenge

Local "Green Teams" and energy champions

Many successful programmes rely on embedded "green teams" or energy champions in each building rather than only a central energy cell. For TMC, one or two Energy Champions per facility (for example, the technician at Main Office, office attendant at Cluster Cell, depot clerk at Wagle, school principals, maternity-home medical officer, Tulshidham society representative) can:

- Remind colleagues about switch-off routines and correct AC setpoints.
- Help interpret monthly dashboards and collect suggestions.
- Coordinate end-of-day walkthroughs to ensure lights, ACs and pumps are off where appropriate.

Light-touch training and regular recognition for these champions will support the broader behavioural programme and ensure messages are aligned with technical upgrades (e.g. explaining new AC controls or pump timers).

Linking behaviour with efficiency and rooftop solar

Global experience indicates that behavioural programmes are most effective when tied to visible technical changes and rooftop solar, so staff can clearly see the impact of their actions on both bills and on-site generation. For TMC, this means deliberately sequencing behavioural campaigns with LED/AC retrofits and the solar roadmap: for example, pairing expansion of solar at Vartaknagar, Cluster Cell or TMC Main Office with campaigns on "using solar wisely" (scheduling loads into solar hours, avoiding waste at night), and using live or monthly solar-generation displays as a motivational tool.

Applied to Thane, these global good practices like clear targets, simple rules, feedback and dashboards, recognition-based competitions, local champions and explicit links to solar, offer a concrete template for embedding behavioural change into TMC's day-to-day operations and sustaining the technical savings identified in the audit.

TMC Solar Report

Thane Municipal Corporation (TMC) has been an early mover on municipal clean energy in Maharashtra. Under national "Solar City" and Urban-LEDS initiatives, TMC has already piloted rooftop solar on its main administrative building, several ward offices, and at least one municipal school, where a ~15 kWp plant now meets a majority of the school's electricity needs (ICLEI South Asia, 2020).

This report presents a rooftop solar potential roadmap for a first batch of priority municipal facilities in Thane. It focuses on:

- Quantifying Phase-1 rooftop solar capacity (kWp) for selected TMC buildings.
- Estimating the share of each building's annual electricity demand that can be met by on-site solar.
- Providing indicative cost and emissions-reduction estimates.
- Situating these projects within the wider state and national rooftop solar ecosystem, including MERC's net-metering regulations and Maharashtra's emerging SMART residential rooftop scheme (Maharashtra Electricity Regulatory Commission, 2019).

The analysis is intended as a practical input for TMC's engineering, planning and finance departments to move from pilot projects to a structured, portfolio-scale rooftop solar programme.

Scope and Buildings Covered

This roadmap aligns with the broader energy-efficiency and behavioural audits conducted for nine TMC buildings, but its Phase-1 rooftop solar focus is on three technically and operationally suitable facilities:

- Cluster Cell Office (administrative / amenity building)
- Tulshidham B2 BSUP residential tower (common areas)
- Wagle Bus Depot (administrative + workshop complex)

These three sites:

- Have relatively favourable roof geometries,
- Show significant and/or continuous electricity demand, and
- Currently do **not** host large grid-connected PV plants (unlike Vartaknagar Ward Office and a pilot municipal school) (ICLEI South Asia, 2015).

For context, the wider TMC building set already includes:

- TMC Main Office, Pachpakhadi (admin HQ)
- Vartaknagar Ward Office (with an existing 25 kWp rooftop plant) (Chen et al., 2021)
- Swa. Meenatai Thakare Maternity Home
- Dadoji Kondev Stadium building
- TMC Schools No. 53 & 55
- Tulshidham BSUP towers B1/B2

Table 1: Buildings Considered in This Roadmap

Sl. No	Building	Use Type	Role in This Roadmap
1	Thane Municipal Corporation HQ, Pachpakhadi	Administrative office	Context; candidate for later phases
2	Vartaknagar Ward Office	Admin + environmental laboratory	Existing 25 kWp PV; showcase site
3	Cluster Cell Office, Wagle Estate	Admin / amenity building	**Phase-1 rooftop PV site**
4	Tulshidham B2 BSUP, Ghodbunder Road	Residential common areas	**Phase-1 rooftop PV site**
5	Wagle Bus Depot (Admin, Transport, Workshop)	Transport depot / workshop	**Phase-1 rooftop PV site**
6	TMC Schools 53 & 55	Education	Potential Phase-2 rooftop PV expansion
7	Swa. Meenatai Thakare Maternity Home	Healthcare	Potential Phase-2 rooftop PV expansion
8	Municipal school (Urban-LEDS net-zero pilot)	Education	Existing ~15 kWp plant (demonstration)

Policy and Scheme Context

Existing TMC Solar and "Solar City" Actions

As part of India's Solar Cities Programme and UN/ICLEI's Urban-LEDS initiative, Thane has:

- Prepared a "Solar City Master Plan" with sector-wise renewable-energy and energy-efficiency targets covering buildings, street-lighting and water supply (Chen et al., 2021).
- Installed rooftop PV on key municipal buildings, including

Swa. Meenatai Thakare Maternity Home

  - Thane Municipal Corporation HQ
  - Several ward offices (including Vartaknagar, ~25 kWp net-metered)
  - At least one municipal school with a 15 kWp grid-interactive rooftop PV plant and efficiency upgrades, which together supply roughly two-thirds of the school's electricity needs (ICLEI South Asia, 2020).

These pilots demonstrate TMC's ability to manage rooftop PV plants and use them as demonstration sites for students and citizens.

Methodology

Data Collection and Baseline EPI Assessment

For each Phase-1 building, baseline electricity performance was established by combining:

- At least 12 months of electricity bills (kWh) where available.
- Total built-up floor area (m²), from TMC records and site checks.
- Typical operating hours and use patterns (office hours, workshop shifts, pump regimes, etc.).

Revised EPIs for key buildings are:

Table 2: Baseline Energy Performance (Selected TMC Buildings)

Sl. No	Building	EPI (kWh/m²·yr)	Performance Band*	Key Focus Area
1	Thane Municipal Corporation HQ	66.85	Moderate - Low	Large 8-floor HQ – HVAC discipline, IT shutdowns, and future rooftop solar
2	Vartaknagar Ward Office, TMC	37.81	Low	Already benefits from 25 kWp PV – maintain good practices, use as showcase
3	Cluster Cell Office, TMC	27.12	Low	Efficient admin block – rooftop solar + occupancy controls, plug-load control
4	Tulshidham B2 BSUP (common areas)**	≈3.8	Very Low	Pump timers & sensor-based lighting; excellent candidate for small rooftop PV
5	Wagle Bus Depot (Admin + Workshop)	28.85	Low	Safety + efficiency; compressor/pum

				p control and rooftop solar

*Performance bands are indicative, based on comparison with typical Indian office, depot and residential-common-area benchmarks and BEE guidance.
**Annual kWh for Tulshidham B2 common areas is estimated from EPI ~3.8 kWh/m²·year and measured built-up area; detailed meters are recommended in future for refinement.

Roof Assessment and Technical Feasibility

For Phase-1 sites, roof potential was evaluated using:

- Satellite imagery to understand gross roof extents and neighbouring structures.
- On-site checks (where available) to identify:
  - Permanent equipment (water tanks, lift rooms, signages).
  - Shading from adjacent buildings, trees and parapets.
  - Access pathways, parapet heights and potential O&M routes.

Usable roof area was taken as **60–70%** of gross roof area after excluding:

- Strongly shaded zones,
- Safety & setback margins (around parapets, edges, skylights), and
- Roof space required for future services.

Solar Resource and System Performance Assumptions

Thane has good solar resources, with global horizontal irradiation (GHI) typically around 5.0–5.2 kWh/m²/day. For Phase-1 modelling we used:

- System performance ratio (PR): **~70–75%**
- Effective annual yield: **~1,400 kWh/kWp/year**, slightly conservative relative to typical Indian rooftop figures (~1,400–1,600 kWh/kWp/year) to account for partial shading, urban dust/soiling and system downtime (Synergy Solar, 2024).
- Tilt: 10–15° on flat RCC roofs.
- Orientation: Approximately south, adjusted for local constraints.
- Long-term degradation: ~0.5–0.7% per year (factored qualitatively into lifetime benefit estimates) (Waaree Renewable Technologies Ltd., 2024).

Sizing Logic and Demand Coverage

Sizing for Phase-1 plants followed three principles:

1. **High self-consumption**: Target 60–70% of annual demand to minimise surplus export and simplify billing.
2. **Modularity**: Leave physical and electrical headroom for Phase-2 expansion once operational experience and demand patterns are better understood.
3. **Operational alignment**: Match PV output to daytime loads – especially offices, pumps and workshop equipment at Cluster Cell and Wagle Bus Depot, and pump + common-area loads at Tulshidham B2.

Using the baseline annual consumption values and the 1,400 kWh/kWp/year planning yield, the team iteratively tested system sizes to achieve approximate annual shares of 65–70% of building demand for the three Phase-1 sites.

Phase-1 Rooftop Solar Potential – Summary

Table 3: Phase-1 Rooftop Solar - Key Parameters

Building	Use Type	Annual kWh (Baseline)	Phase-1 Size (kWp)	Est. Generation (kWh/yr)*	Approx. Share of Demand Met	Indicative CAPEX (₹ lakh)**	Existing PV Assets?
Cluster Cell Office, TMC	Admin / amenity building	168,636	77.7	≈109,600	~65%	~46.6	No grid-connected PV at present
Tulshidham B2 BSUP (common areas)	Residential common + pumps	≈15,320	7.6	≈10,700	~70%	~4.6	No PV; strong community-demonstration value
Wagle Bus Depot (Admin + Workshop)	Depot admin + workshop loads	159,791	79.9	≈111,900	~70%	~47.9	No PV; high visibility for TMC operations
Total / Phase-1	—	≈343,700	**165.2**	**≈232,200**	—	**≈99.0**	—

**Generation values are approximate, consistent with 1,400 kWh/kWp/year planning yield, rounded to nearest hundred.*
***CAPEX is estimated at ₹60,000/kWp as a mid-range benchmark for institutional rooftop systems in India; actual tendered prices may vary (Loom Solar 2024).*

Building-wise Narratives

a) Cluster Cell Office, TMC – 77.7 kWp (~65% of demand)

Baseline
Cluster Cell is a relatively efficient administrative/amenity building with an EPI of ~27 kWh/m²·year, well within the "low" band for Indian offices. However, it still consumes about 168,600 kWh/year due to:

1. Multiple air-conditioned office areas,
2. Dense IT loads (computers, printers, servers),
3. Common-area lighting and lifts.

No major rooftop PV plant is currently installed at this facility.

Solar potential and sizing
A 77.7 kWp rooftop system, installed on the main RCC roof and any suitable ancillary roofs, is expected to generate ≈109,600 kWh/year under the conservative 1,400 kWh/kWp assumption. This would meet roughly **65% of Cluster Cell's annual electricity demand** on an energy-balance basis, with most generation aligning to daytime office loads.

Design considerations

- **Layout**: Array blocks arranged to maintain maintenance corridors and clear access to roof-top water tanks and lift rooms.
- **Inverters**: 2–3 string inverters sized to ensure adequate DC:AC ratio and fault redundancy.
- **Interconnection**: AC coupling at the LT panel serving common loads, with bidirectional net metres in coordination with MSEDCL.

Synergies with efficiency and behaviour

- Pair PV with **AC set-point discipline (24–26°C)**, elimination of after-hours idle IT loads, and improved daylight use in office areas to maximise self-consumption.
- Integrate a simple **lobby dashboard** displaying solar generation and consumption, reinforcing behavioural campaigns and showcasing savings to staff and visitors.

b) Tulshidham B2 BSUP – 7.6 kWp (~70% of common-area demand)

Baseline
Tulshidham B2 is a high-rise BSUP residential tower where common-area loads (water pumping, staircase and corridor lighting) account for most electricity consumption. The EPI for common areas is very low (~3.8 kWh/m²·year), but pumps are manually operated for extended periods and corridor lights are not sensor-controlled.

Estimated annual consumption for B2 common areas is ~15,300 kWh.

Solar potential and sizing
A modest **7.6 kWp** rooftop plant, located on the tower's main terrace, is expected to generate about **10,700 kWh/year**, covering **approximately 70% of common-area electricity demand** when combined with:

- Timers/level controllers on water pumps, and
- LED/sensor retrofits for staircase and corridor lighting.

Design considerations

- **Shared rooftop**: The array must be compatible with existing uses (drying spaces, small antennae), with clear access and railings for safety.
- **Net metering vs. common-meter model**: The simplest model is to connect the plant to the **common services meter** (society/TMC meter for common loads). Over time, TMC could explore **virtual net metering** or other shared-credit mechanisms so residents benefit directly from surplus, leveraging emerging national guidance on group/virtual net metering (The Green Bein, 2025).

Community demonstration role

Because Tulshidham is a BSUP housing complex, this plant can serve as a flagship demonstration for low-income residential solar in Thane, complementing the state's SMART residential rooftop scheme and central PM Surya Ghar subsidies (Times of India, 2025).

c) Wagle Bus Depot – 79.9 kWp (~70% of admin + workshop demand)

Baseline
Wagle Bus Depot combines:

- Administrative spaces,
- Ticketing/traffic control,
- Workshop areas with compressors, pumps, welding machines and other heavy equipment.

The building's EPI is ~28.9 kWh/m²·year, but absolute consumption is significant at ~159,800 kWh/year, and there are major **electrical-safety and envelope issues** (open wiring, broken windows, structural cracks), which simultaneously raise risk and cooling loads.

Solar potential and sizing
A **79.9 kWp** rooftop PV system distributed across the depot's main roofs can generate roughly **111,900 kWh/year**, meeting about **70% of annual electricity demand** once basic efficiency and safety upgrades are in place.

Design considerations

- **Pre-condition**: Electrical safety and structural repair (wiring, junction boxes, broken glazing) should be treated as non-negotiable prerequisites before PV installation.
- **Zoning**: Map loads into admin + workshop circuits to ensure that solar supports both day-time office functions and core depot operations.
- **Soiling & maintenance**: Workshop environments tend to be dusty; O&M contracts must emphasise regular cleaning and visual inspections.

Operational integration

- Use PV generation to buffer workshop loads during the daytime, reducing demand charges and exposure to tariff hikes.
- Link the solar project to **behavioural SOPs** around equipment shutdown (compressors, welders, lights), so that PV offsets productive loads rather than wastage.

d) Existing PV at Vartaknagar, TMC HQ and Municipal School

The Phase-1 roadmap builds on existing TMC rooftop assets:

- **Vartaknagar Ward Office** hosts a 25 kWp net-metered rooftop system that already offsets around 40–45% of the building's annual electricity consumption, making it one of TMC's best-performing admin facilities in EPI terms.
- The **TMC HQ** and selected ward offices have grid-interactive solar PV systems totalling over 100 kWp under earlier Solar City actions.
- An Urban-LEDS pilot **municipal school in Thane** has been retrofitted with efficiency measures and a ~15 kWp rooftop PV plant, enabling it to meet a majority of its energy needs from on-site solar and serve as a "net-zero" demonstration.

These installations provide valuable implementation experience, procurement templates, and community-facing examples that TMC can leverage when scaling the Phase-1 plants and designing subsequent phases (HQ, Schools 53 & 55, maternity home, stadium).

Financial and Cost-Benefit Analysis

Capital Costs

Using a planning benchmark of **₹60,000/kWp** for institutional on-grid rooftop systems (modules, inverters, structures, cabling, installation, basic monitoring), consistent with recent India-wide market estimates, indicative CAPEX is:

- Cluster Cell Office (77.7 kWp): ~₹46.6 lakh
- Tulshidham B2 BSUP (7.6 kWp): ~₹4.6 lakh
- Wagle Bus Depot (79.9 kWp): ~₹47.9 lakh

Total Phase-1 CAPEX ≈ ₹0.99 crore (₹99 lakh).

Annual O&M is expected to be 1–2% of CAPEX (~₹1–2 lakh/year for the portfolio), covering cleaning, inspections and minor repairs.

Electricity Bill Savings

With combined annual generation of ≈232,000 kWh/year and an average effective tariff of **₹8–9/kWh** for municipal services (energy + demand charges + taxes), avoided electricity purchases are on the order of:

- **₹18.5–₹21.0 lakh per year** across the three buildings.

This implies a **simple payback of around 5–6 years**, with strong protection against future tariff increases and scope for even better economics if TMC aggregates capacity and secures competitive bidding.

Emissions Reductions

Using a grid emission factor of **~0.82 kg CO_2/kWh** from India's CO_2 baseline database for the power sector, the annual emissions avoided by Phase-1 plants are:

- 232,000 kWh/year × 0.82 kg CO_2/kWh ≈ **190 tCO_2e/year**

Over a 25-year plant life (ignoring minor degradation for simplicity), this equates to around:

- **4,700–4,800 tCO_2e** of cumulative avoided emissions.

Wider Co-Benefits

Beyond direct financial and GHG benefits, Phase-1 rooftop solar will:

- Improve **energy resilience** for key municipal functions (depot operations, amenity building services, BSUP common utilities).
- Reinforce Thane's image as a **Solar City and climate-forward municipality**, building on existing Urban-LEDS and Solar City pilots.

- Provide tangible, visible examples for **public communication**, particularly at Tulshidham BSUP, where residents can see solar directly powering pumps and lighting.
- Support staff engagement and behavioural programmes by linking everyday practices (switch-off discipline, efficient scheduling) to visible solar performance dashboards.

Implementation Roadmap

Phase 1 – Preparation (0–6 months)

Institutional set-up

- Establish or reinforce a small **Municipal Solar Cell** within TMC, housed under the Environment/Energy or Electrical department, with representation from planning, finance and legal.
- Nominate **facility-level nodal officers** for Cluster Cell, Tulshidham B2 and Wagle Bus Depot.

Technical due diligence

- Conduct structural assessments to confirm rooftop load-bearing capacity, wind loads and waterproofing requirements for each site.
- Finalise usable roof areas and preliminary array layouts, including walkways and safety features.
- Map existing electrical distribution, identify interconnection points and carry out preliminary protection studies (breaker ratings, fault levels).

Refined techno-economic analysis

- Update CAPEX and OPEX estimates with vendor quotations.
- Validate baseline kWh figures against the latest 12–24 months of bills.
- Run sensitivity analyses for different tariffs and yield assumptions (e.g., 1,300–1,600 kWh/kWp/year).

Scheme and regulatory alignment

- Engage early with **MSEDCL** for net-metering applications and clarifications on rooftop capacity caps specific to these consumer categories.
- Assess options for leveraging concessional financing or performance-based grants via state or national programmes where municipal/institutional entities are eligible.

Phase 2 – Procurement and Installation (6–18 months)

Bundled procurement

- Issue a single **EPC tender** covering all three Phase-1 plants (and optionally any additional capacity at Vartaknagar or Schools 53 & 55) to:
    - Achieve economies of scale,
    - Standardise technical specifications (modules, inverters, structures), and
    - Simplify O&M.

Implementation sequencing

- **Wagle Bus Depot** – After safety and envelope repairs are completed, given its high visibility and strong savings potential.
- **Cluster Cell Office** – As a flagship administrative building with good monitoring access and staff engagement potential.
- **Tulshidham B2 BSUP** – As a community-facing demonstration project tied to pump automation and lighting retrofits.

Net-metering and commissioning

- Complete all net-metering procedures (application, site inspection, bi-directional meter installation, agreement signing) with MSEDCL for each site.
- Commission systems with proper testing, including PR checks, insulation tests and safety drills for maintenance staff.

Phase 3 – Monitoring, Optimisation and Scale-up (18–36 months)

Monitoring and verification

- Install simple **online monitoring** or data-logging for each plant to track daily and monthly generation, PR and downtime.
- Integrate PV generation data with building-level energy-efficiency monitoring (EPIs, monthly kWh trends).

Behavioural and operational integration

- Display solar performance on notice boards or digital screens at Cluster Cell and Wagle Depot, linking it to **behavioural campaigns** (e.g., "Help us turn 70% solar by switching off unused loads").
- Adjust AC schedules, pump timings and lighting controls to align with solar generation profiles where possible.

Scale-up to additional municipal buildings

Use lessons from Phase-1 to prepare a **Phase-2 pipeline**, potentially including:

- TMC Main Office, Pachpakhadi (larger rooftop plant, leveraging prior Solar City experience).
- Swa. Meenatai Thakare Maternity Home (with careful clinical load analysis).
- Dadoji Kondev Stadium (for event-linked prominence).
- TMC Schools 53 & 55 (complementing the existing Urban-LEDS net-zero school).

Risk Assessment and Mitigation

Table 4: Key Risks and Mitigation Strategies

Risk Category	Description / Example	Suggested Mitigation
Regulatory / approvals	Delays in net-metering approvals, ambiguity on caps or parallel open access	Early engagement with MSEDCL; standardised documentation; tracking latest MERC orders and guidance

Structural / technical	Roof not structurally adequate, water-proofing issues, unexpected shading	Detailed structural audit; conservative array loading; integrated drainage and waterproofing design
Electrical safety	Existing wiring defects or overloaded panels (esp. Wagle Bus Depot) impacting plant safety and reliability	Complete safety rectification works first; coordination with electrical inspector; robust protection & earthing design
Performance / O&M	Poor cleaning and maintenance leading to reduced yield and inverter faults	Multi-year AMC with clear KPIs; training TMC electricians; simple monitoring dashboards to flag underperformance
Financial	Tariff structure changes, lower-than-expected yield or higher O&M affecting payback	Conservative yield assumptions; contingency in financial planning; exploring concessional lines or grants where possible
Social / institutional	Limited ownership from facility staff or residents (Tulshidham), vandalism, access issues	Early consultations; assign building-level solar champions; visible benefit communication; clear access and safety norms

Conclusion

This rooftop solar potential roadmap for Thane Municipal Corporation shows that:

- A first tranche of **three priority buildings** (Cluster Cell, Tulshidham B2 BSUP and Wagle Bus Depot) can host around **165 kWp** of rooftop PV.
- These Phase-1 systems can collectively generate roughly **232,000 kWh of clean electricity each year**, meeting about **65–70%** of annual demand in the targeted buildings.
- With an indicative CAPEX of **~₹1.0 crore** and annual savings approaching **₹19–20 lakh**, simple payback is in the **5–6 year** range, with substantial emissions reductions (~190 tCO_2e/year).

When integrated with ongoing energy-efficiency upgrades and behavioural programmes across TMC facilities, rooftop solar becomes a central pillar of Thane's path toward climate-aligned municipal operations. Building on earlier Solar City and Urban-LEDS pilots, the proposed Phase-1 plants provide a replicable template for scaling rooftop solar across Thane's wider municipal portfolio and for mobilising residential solar adoption under schemes like SMART and PM Surya Ghar.

Done well, this roadmap will allow TMC to **"walk the talk"** on energy efficiency and renewable energy, turning its own offices, depots and housing complexes into visible examples of the low-carbon, climate-resilient city it aims to build.

Way Forward

The Light-Touch Support initiatives implemented in Chandrapur, Navi Mumbai, and Thane demonstrate how focused, low-cost interventions can translate climate intent into measurable outcomes within existing municipal capacities. These city-led pilots show that even without large capital investments, targeted actions—such as heat-resilient building measures and behavioural energy efficiency—can deliver immediate benefits in terms of thermal comfort, energy savings, and operational efficiency, while strengthening local readiness for deeper decarbonisation efforts.

A key takeaway from this phase is the scalability of light-touch approaches when they are designed to align with routine municipal functions. Interventions tested through this support—cool roof applications, passive cooling measures, operational energy improvements, and staff-led behaviour change—are inherently replicable. They can be rapidly scaled across wards, building typologies, and additional cities using standardised technical specifications, implementation templates, and simple monitoring frameworks developed during this phase.

Going forward, cities can embed these interventions into existing policy instruments and programmes, including Heat Action Plans, municipal building operation protocols, annual maintenance budgets, and city energy management systems. For Chandrapur, this offers a pathway to expand heat-resilience measures across vulnerable neighbourhoods, while Navi Mumbai and Thane can institutionalise behavioural energy efficiency as a core component of municipal building management. Integrating these actions into routine planning and budgeting cycles will be critical to sustaining impact beyond pilots.

Institutionalisation and capacity building will play a central role in scaling light-touch solutions. Empowering municipal departments, facility managers, and frontline staff with clear guidance, training, and ownership mechanisms will ensure that these interventions become standard practice rather than one-off initiatives. Peer-to-peer learning across cities—facilitated through state platforms and networks—can further accelerate adoption by sharing implementation lessons, performance data, and adaptable models.

From a financing perspective, the low capital intensity of light-touch interventions creates opportunities to mobilise municipal funds, state schemes, CSR resources, and performance-based financing with minimal fiscal risk. Demonstrated savings and co-benefits from this phase can help cities build a strong business case for scaling and, over time, unlock larger investments in energy efficiency and renewable energy.

Overall, the Light-Touch Support approach offers a practical and replicable entry point for cities to advance climate action at pace. By scaling proven solutions, embedding them within municipal systems, and leveraging peer learning and state support, Maharashtra's cities can rapidly expand the impact of these interventions—laying the groundwork for more comprehensive, investment-ready decarbonisation and resilience efforts in the years ahead.